

Supervisor: **Dr. Ma Hong**
Author: **Mario Toledano Rubio**

Master: **Supply Chain, Logistics and Mobility**
Chinese University: **Zhejiang University**
Spanish University: **Polytechnic University
of Catalonia**

Date: **June, 2016**



DESIGN AND ECONOMIC STUDY OF A CONVENTIONAL WAREHOUSE AND AN AUTOMATED WAREHOUSE

Table of Contents

ABSTRACT	4
INTRODUCTION	5
INITIAL DATA	5
CONVENTIONAL WAREHOUSE	8
DYNAMIC CAPACITY	8
WAREHOUSE FLOW	8
DESIGN OF THE SELVES	9
Checking deflection	10
Design of the shelves.....	13
EXPEDITION AND RECEPTION.....	17
Reception Area	17
Reception area sizing	21
Expedition Area	22
Expedition area sizing.....	25
DOCKS.....	26
Number of docks	26
Reception area	26
Expedition area	27
Required operators	28
CORRIDORS.....	28
LAYOUT.....	29
Silo	29
Distribution.....	29
FORK LIFT.....	31
PICKING AREA.....	32
REQUIRED OPERATORS	33
STRUCTURAL FEATURES	33
CONCRETE BASEMENT	34
PILLARS	41
REINFORCED CONCRETE FLOORING.....	42
PAVING SURFACE	43

PREFABRICATED BEAMS.....	43
WALLS.....	45
ROOF	46
FINAL DESINGN.....	47
AUTOMATED WAREHOUSE.....	48
GENERAL DESCRIPTION	48
DYNAMIC CAPACITY	48
WAREHOUSE FLOW.....	49
SHELVES.....	50
Checking deflection	50
Design of the shelves.....	53
Width of the corridors.....	55
Total area of the Silo	55
TECHNICAL DATA.....	58
Work Processes	59
AVERAGE CYCLE TIME OF SHUTTLES.....	64
Simple Cycle	65
Combined Cycle.....	66
RECEPTION AND EXPEDITION AREA.....	67
Reception Area	67
Expedition area	69
Reception Area Sizing.....	70
Expedition Area Sizing.....	71
PICKING AREA.....	71
REQUIRED OPERATORS	72
WAREHOUSE FEATURES.....	72
STRUCTURE	72
FOUNDATION	73
SLAB.....	74
COVER AND WALLS	74
DRAINS	75
FIRE MECHANISM.....	75
FINAL DESIGN	75
BUDGET	77

CONVENTIONAL WAREHOUSE 77

AUTOMATED WAREHOUSE 78

ECONOMIC STUDY 79

 Recovery or "Pay-Back" period 81

 NPV (Net Present Value) 82

 IRR (Internal Rate of Return) 83

CONCLUSIONS 84

BIBLIOGRAPHY 84

ABSTRACT

The main objective of this project is design and doing an economic study of an automated warehouse and a conventional one.

A Spanish company provides the data for the calculation of the warehouse. Taking into account: demand, seasonality, product features, dimensions of the pallets, etc..

First step is to calculate the conventional warehouse, the sizing of the silo, reception area and area of expedition. The sizing of the picking area, the required number of docks and the number of operators for each area are also calculated.

The second important block of the project consists on sizing the automated warehouse, dimensions of the silo and the areas of reception and expedition are calculated. It is also calculated the size of the picking area, the number of shuttles that will be needed in the silo and the number of docks.

Last step is to make a budget for each warehouse and see the behavior for a period of 20 years then decide which warehouse it would be better from the economic point of view. For doing the economic study three methods will be used:

- Pay-Back
- NPV
- IRR

Finally the automated warehouse, despite of being more expensive to implement, their operational costs are much lower than the conventional one so finally the automated warehouse will be more profitable than the conventional warehouse.

INTRODUCTION

“Telas Belda” is a Spanish company related with clothes and fabrics. Nowadays they are having a space problem, the company is growing up and they want to expand to other countries so they need another warehouse. The company wants to know which kind of warehouse (automated or conventional) would be better for them. In order to carry out this design, initial data have been provided by the company: characteristics of the product to be stored, seasonality of demand, unit handling, hours of operation, etc.

INITIAL DATA

Data conditions	
Kind of pallet	% of picking
1	30
2	40
3	40
4	0

Table 1. Picking conditions

Hours restriction																					
Hours (h)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22				
Inputs																					
Outputs																					
Expedition routes																					

Table 2. Hours restricion

Pallet	Dimensions	Height (mm)	Weight (kg)	Total Units	Dry	Flammable	Chemical not Flammable	Entrances / Exits per Day
1	800 x 1200	800	750	14.000	50%	30%	20%	600
2	800 x 1200	1.250	1.000	5.000	60%	30%	10%	300
3	800 x 1200	2.000	1.000	2.000	60%	30%	10%	250
4	800 x 600	1.000	450	2.000	80%	--	20%	400

Table 3. Initial data

There is also a data related with the seasonality of outputs for each month. Below is exposed for each month and for every pallet the number of outputs:

Pallet	January	February	March	April	May	June	July	August	September	October	November	December
1	420	420	600	600	600	780	600	360	600	600	840	600
2	210	210	300	300	300	390	300	180	300	300	420	300
3	175	175	250	250	250	325	250	150	250	250	350	250
4	280	280	400	400	400	520	400	240	400	400	560	400

Table 4. Seasonality in exits of pallets

The total output per day is calculated by comparing the entries and the stock produced in each month. With this quantity the accumulated stock is calculated by adding to that generated in the month i for the month $i-1$:

	January	February	March	April	May	June	July	August	September	October	November	December
Exits	1085	1085	1550	1550	1550	2015	1550	930	1550	1550	2170	1550
Entrances	1.550	1.550	1.550	1.550	1.550	1.550	1.550	1.550	1.550	1.550	1.550	1.085 ¹
Stock	465	465	0	0	0	-465	0	620	0	0	-620	-465
Accumulated Stock	465	930	930	930	930	465	465	1.085	1.085	1.085	465	0

Table 5. Accumulated Stock

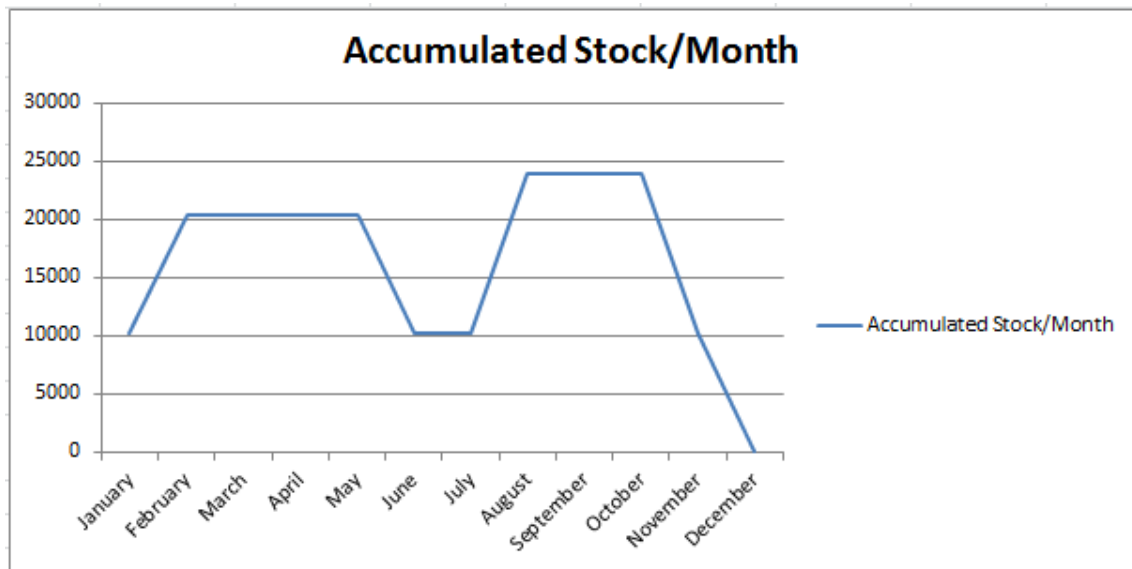
¹ Corresponding to December have been imposed entries that are less than due to be for the rest of the year (1550) trying to balance the annual outputs with annual inputs and to let that the stock accumulated at the end of the year will be zero. In this way, the store will be dimensioned in order that the beginning of each year will be with empty warehouse.

In order to obtain some figures that allow the dimension that will finally adopt the store, the amount of stock accumulated per month is calculated, taking into account that each month has 22 working days:

	January	February	March	April	May	June	July	August	September	October	November	December
Accumulated Stock/Month	10230	20460	20460	20460	20460	10230	10230	23870	23870	23870	10230	0

Table 6. Accumulated Stock per Month

Next graphic represents the evolution of the stock during the year:



Graphic 1. Accumulated Stock

It is noted as there are two periods in which the large-capacity storage works (February to May and August to October). On the other hand, between June and July and in November will be a great movement in expedition area due to the increment of output.

The static capacity is the maximum amount of product that can contain a warehouse for a period of time determined without rotation.

Thus, it is established that the maximum volume of stock in the store hosted will be equal to the static capacity. As shows the above table (table 6), the month in which there is greater demand for storage (maximum cumulative stock) is the month of August. Due to the existence of a maximum valley in sales this month, the dimension of the storage will be for 23870 Pallets. Therefore, the store silo will be sized for this data.

CONVENTIONAL WAREHOUSE

DYNAMIC CAPACITY

Dynamic capacity is refer to the quantity of average stock that rote in the warehouse in a determined period. It is calculated as follows:

$$\text{Dynamic Capacity} = \frac{\sum(\text{Inputs or Outputs}) \times 22 \text{ Working days}}{12 \text{ months}}$$

As it has explained in note 1, inputs and outputs are balanced warehouse therefore can be used interchangeably values for each calculation. Thus it is obtained that the value of the dynamic capacity is 33248 pallets.

The rotation value could be also calculated through the next expression:

$$\text{Rotation} = \frac{\text{Dynamic Capacity}}{\text{Static Capacity}} = \frac{33248}{23870} = 1,39 \text{ months}$$

This data indicates the time period of time in which theoretically all merchandise contained in the store is renewed.

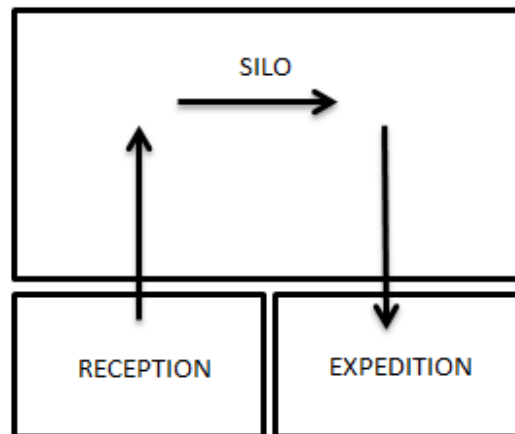
WAREHOUSE FLOW

The flow design of the warehouse will be U-shaped, rather than use a laminar flow. The main reason is that in this way, they can share the resources used in the header.

On the one hand, the entrances in the store are produced from 6am to 16h. Handling systems used in this area are used from 6am to 20pm (to clear the area). On the other hand, the outputs take place from 10h to 22h but handling systems used in this area are active from 8h to 22h. There is a time interval in which inputs and outputs work at the same time. Therefore, from 6am to 8am the resources used in the dispatch area will provide support (if necessary) in the reception area, being in that range unutilized. The same happens from 20h to 22h, but reversed, that is to say, the reception area can support the dispatch area. The resources of the reception and expedition areas are calculated for work in independently way. However, if

there is any fault or maintenance in handling such systems, contingency of different types, etc., it could resort to this alternative.

Moreover, as the inputs and outputs of the trucks meet during an interval of time (from 10h to 16h), it could be the case in which entrances go directly to the dispatch area, bypassing the silo. This can be done as long as the case of pallets where it is not necessary to pick and these movements are recorded in the information system (ERP).



DESIGN OF THE SHELVES

The shelves chosen will be conventional Push-Back with double deep. This type of shelving allows greater flexibility when handling the merchandise, and even more if stored in double depth, as in this case. This system provides a certain inclination to the shelf, so affecting its overall height, as explained afterwards.



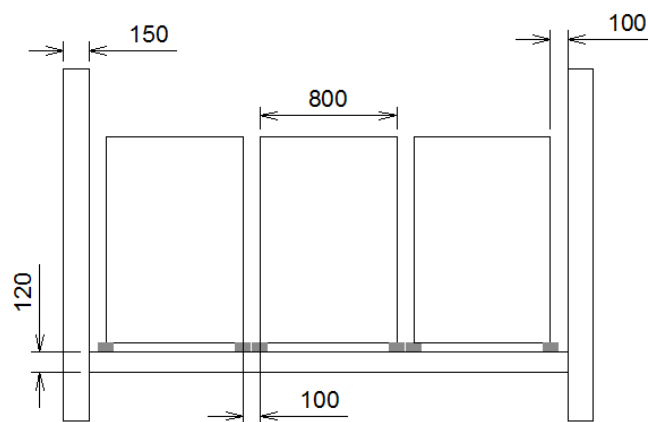
Image 1. Push Back shelve

Each shelf module, between support and support, three pallets are placed longitudinally in two depths, that means there will be six pallets per level and module.

Checking deflection

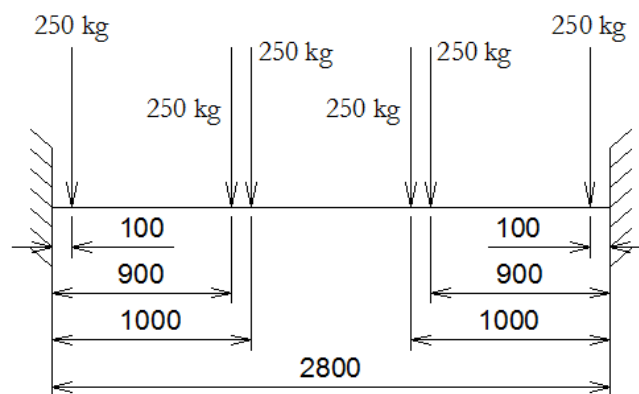
Then it is checked if deflection beam shelves not exceed the maximum provided by Spanish regulation, which is equal to $L / 500$ (where L is the length of the beam span).

Between support and support, 6 pallets are placed, in 2 rows of 3 pallets. Each pallet is placed on two supports (push back) and two beams, so that the total load of each pallet is distributed actually in four different points.



Pallets disposed in the shelf (distances in mm)

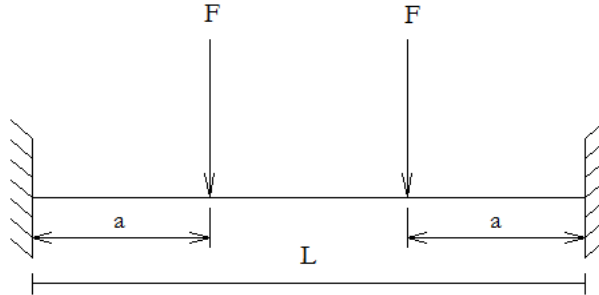
Each pallet then exerts two points of charge of 250 kg on the crossbar, which means that in total are applied to the spar 3 pairs of symmetrical point loads. As the beams are attached to the supports by welding, their behavior can thus assimilate to a fixed-end beam. Therefore, this would be the graphically representation:



Symmetrical loads in the beam (distances in mm)

In the case of the application of 2 point and symmetrical loads, the maximum deflection (located at the midpoint) is calculated by the following expression:

$$y_{\max} = \frac{Fa^2}{24EI} \times (3L - 4a)$$



Where,

F; the applied load

a; the distance between the point of application of force and the end of the beam nearest

L; the total length of the beam

E; the modulus of elasticity

I; the inertia of the beam

The beam can be approximated to a rectangular hollow profile of dimensions 120 * 60 * 4 mm:

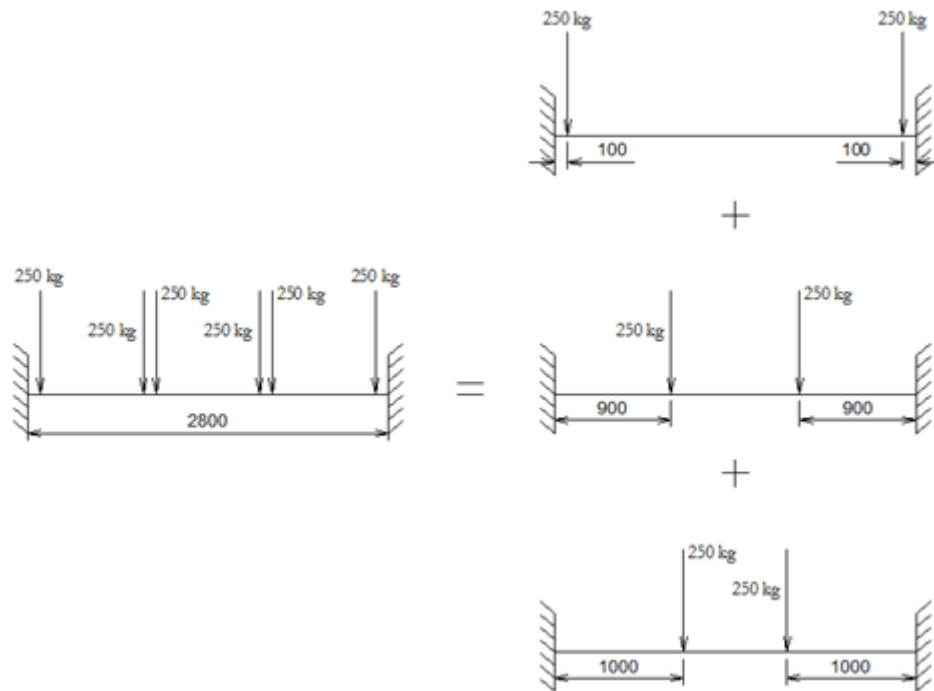
Height (mm)	Width (mm)	Thickness (mm)	Inertia (cm ⁴)
120	60	4	210
120	60	5	241
120	60	6	277

Table 7. Inertias

Verification:

The total inertia of the section could be discomposed into the sum of three inertias:

$$y_{TOT} = y_{a=0,1m} + y_{a=0,9m} + y_{a=1m}$$



Decomposition of the deflections in order to simplify the calculations

The deflection is estimated with the following values, corresponding to our bar:

F ; is 2452 N ($250 \times 9,81$)

a ; is 0,1 m; 0,9m and 1 m respectively

L ; is 2,8 m

E ; is a constant and takes value for iron $200 \cdot 10^9$ N/m²

I ; is $2,1 \cdot 10^{-6}$ m⁴

Finally, the total Inertia:

$$y_{TOT} = 0,02 \text{ mm} + 0,9 \text{ mm} + 1,07 \text{ mm} = 1,99 \text{ mm}$$

The maximum deflection allowed, according to the Spanish Normative (UNE), is:

$$y_{NORM} = \frac{L}{500} = 5,6 \text{ mm}$$

Therefore, the normative is accomplished:

$$y_{NORM} = 5,6 \text{ mm} > y_{TOT} = 1,99 \text{ mm}$$

Design of the shelves

Two types of shelves have been considered for this store design: conventional and compact. The reasons why it has decided to choose the conventional shelves are exposed in the next lines:

What is a compact system shelves: It is a system developed to store homogeneous products, with great quantity of pallets per reference. This type of installation is constituted by a set of shelves that could be move by rails trying to optimize the available space.

Its main advantage is that it saves space because these shelves are still a storage system that does not require aisle. However, to load and unload the pallets the truck waste much time because the corridors must be prepared, other point is that this system needs more ahead of time for prepare the orders trying to minimize the movements in shelves. For this reasons it was decided to remove this option because there is an abundant number of inputs and outputs, which would increase too much time.



Image 2 Compact Shelve

Concerning to the design of the shelves, must consider different aspects about the products:

- Differentiation between nonflammable and flammable goods: the pallets containing flammable product will be stored in separate shelves.
- The height of the different types of pallets: each type of pallet has a different height, so that conditions the measures that each level of the shelves must have, the space should be optimize as much as possible.
- Pallet types: the pallet type 4 is half pallet because its measures are 800 x 600. This fact gives the possibility that the management can be performed in pairs (as if it were a Europallet 1200x800).

Proportion of each pallet in relation with the total:

Pallet	% of the static capacity
1	0,387
2	0,194
3	0,161
4	0,258
Static capacity	1550

Table 8. Percentage of pallets

The next table shows the amount of different pallets taking into account that the pallets 4 are manipulated in pairs:

Pallet	Number of pallets
1	9240
2	4620
3	3850
4	3080

Table 9. Number of pallets

Moreover, it is important for calculations to differentiate the heights of each type of pallet, the levels will be dimensioned according to the heights. The quantities of pallets for the next table are extracted from the proportions shown in the table 8, considering that 30% of the pallets 1, 2 and 3 contain flammable product:

Pallet	Height (mm)	Flammable	Not Flammable	Total
1	0,8	2772	6468	9240
2	1,25	1386	3234	4620
3	2	1155	2695	3850
4	1	0	3080	3080

Table 10. Amount of pallets according to the height

Once it has identified the amounts of pallets for the different heights and the pallets classified among flammable and nonflammable, it can determine the position of the rack in which will be placed according to their height.

It is important to take into account:

- Arrange the pallets with flammable products in some shelves and the rest in other.
- Arrange the pallets on different floors depending on your height, placing them increasingly: low to higher altitudes starting from the ground level.
- The shelves have 5 floors due to the difficulty in the operations.

According to these considerations:

Total of flammable	5313	Different levels for pallet (depend on the height)	
Pallets/Floor	1062,6		
Nº of pallets of kind 1	2772	2,609	2 levels of 0,8 m
Nº of pallets of kind 2	1386	1,304	1 level of 1,25 m
Nº of pallets of kind 3	1155	1,087	2 levels of 2 m

Table 11. Required number of floors for each kind of pallet. Flammable products

Total of not flammable	15477	Different levels for pallet (depend on the height)	
Pallets/Floor	3095,4		
Nº of pallets of kind 1	6468	2,090	2 levels of 0,8 m
Nº of pallets of kind 2	3234	1,045	1 level of 1,25 m
Nº of pallets of kind 3	2695	0,871	1 levels of 2 m
Nº of pallets of kind 4	3080	0,995	1 levels of 1 m

Table 12. Required number of floors for each kind of pallet. Not flammable products

Once obtained the number of levels for each type of pallet, the height of the shelves is obtained. That is conditioned by three characteristics of the shelves:

- The angle of inclination having the shelf is 5 degrees.
- The margin between the top of the goods and the bottom of the top rail is 0.25 m.
- The height of each crossbeam measured 0,12 m (there are 5 crossbeams per height). There is a total of 0,6 m.
- It is dimensioned in order to the highest pallets standing on the level 5, thus optimizing space.

Flammable product		
Level	Height for the fork-lifts (m)	Total height of the warehouse (m)
Level 4	2,25	8,9
Level 3	1,5	
Level 2	1,05	
Level 1	1,05	
Crossbeam	0,6	
Total	6,45	

Table 13. Height for the shelves. Flammable products

The first data column shows the height that the forks must be rise (for that reason is not taken into account the height of the pallet on the top level). The result is a height of 6,45 m, so is combinable with reach fork-lifts, which can reach that height.

In the second column appears the total height of the shelf taking into account also the height of the pallet on the top level. The result of 8,7 m is the sum of the previous value, 6,45 m, 2 m and 0,214 m (height provide by the 5 degrees of angle of inclination of the shelf).

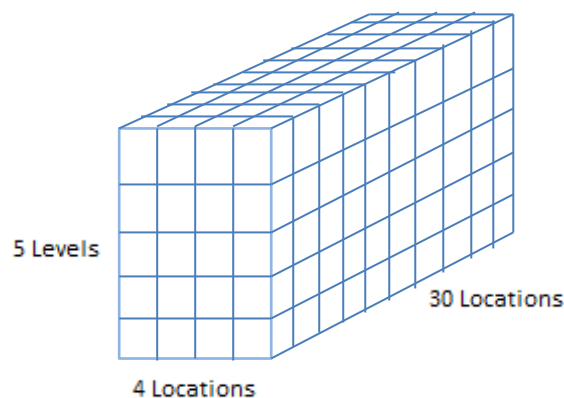
Not flammable product		
Level	Height for the fork-lifts (m)	Total height of the warehouse (m)
Level 4	1,5	7,7
Level 3	1,25	
Level 2	1,05	
Level 1	1,05	
Crossbeam	0,6	
Total	6,45	

Table14. Height for the shelves. Not flammable products

The shelves of nonflammable products, respecting the same calculations as in the above table, have a working height for the fork-lifts of 5,45 m, while the total height taking into account the merchandise is 7,7 m.

It is taken into account for calculating the number of shelves the following:

- The store will be along the 30 pallets shelves.
- The shelves are double depth (there are 4 pallet widths in each shelf).
- There are 5313 flammable pallets and 15477 nonflammable.
- The shelves have 5 levels.



The total amount of locations in each section will be $5 \times 4 \times 30 = 600$ Locations

The result in terms of number of shelves is: 9 shelves for flammable products and 26 shelves for other goods. In total, 35 shelves in the store.

The calculations knowing the occupied area, taking into account different parameters:

- The number of supports is 11.
- The average measure of support is 0,15 m.
- The number of modules is 10.
- The length of the pallet along the shelf is 0,8 m.
- The clearance between pallet and between the pallet and support is 0,1 m.

The length of a shelf module is calculated as:

$$M = \text{width of support} + (\text{clearance between pallets } (0,1) * 4) + (\text{length of the pallet } (0,8) * 3)$$

$$M = 0,15 + (0,1 * 4) + (0,8 * 3)$$

$$M = 2,95 \text{ m}$$

The total length of the shelf is:

$$L = \text{length of de module} * 10 + \text{support}$$

$$L = 2,95 * 10 + 0,15$$

$$L = 29,65 \text{ m}$$

As for the width of the shelf is taken into account:

- Shelves have double depth, and are grouped in pairs. Each pallet is 1,2 m, so the total amount is 4,8 for 4 pallets.
- The clearance between pallets is 0,1 m.
- The width of the crossbeam is 0,1 m by 4 crossbeams (0,4 m).

The width of the shelves is the sum of the last data and is 5.5 m.

Therefore the required total area will be:

$$A = \text{length} * \text{width}$$

$$A = \text{length} * \text{width} * \text{num. shelves}$$

$$A = 29.65 * 5.5 * 35 = 5707,625 \text{ m}^2$$

EXPEDITION AND RECEPTION

This section will describe the reception area and the expedition area that is the head of the warehouse. It will determine the size and the number of workers.

Reception Area

During the year, the volume of arrivals in the warehouse is constant and equal to 1550 pallets / day, except for the month of December, when the volume is less and equal to 1085 pallets / day. However, the area must be dimensioned for the biggest volumes of inputs, which mean 1550 pallets / day.

The arrivals of the pallets are made from 6am to 16h. Assuming that inputs are constant distributed in time, we have:

$$\frac{Inputs}{Hour} = \frac{Inputs/day}{Inputs/day} = \frac{1550}{10} = 155 Inputs/h$$

Therefore, trucks bring to the store 155 pallets per hour from 6h to 16h.

With the intention of minimizing labor and machinery necessary in inputs area, the following two assumptions are made, although from 16h ceases the arrival of trucks:

- **Scenario 1: The workers work from 6 h to 22 h**
- **Scenario 2: The workers work from 6 h to 20 h**

In other words, it will not systematically clearing the area of inputs as the pallets were coming. The pallets will accumulate gradually until 16h, and from 16h to 22h (Hypothesis 1) or from 16h to 20h (Scenario 2), the workers will responsible for placing on the silo remaining pallets, thus emptying the entry area at the end of the workday.

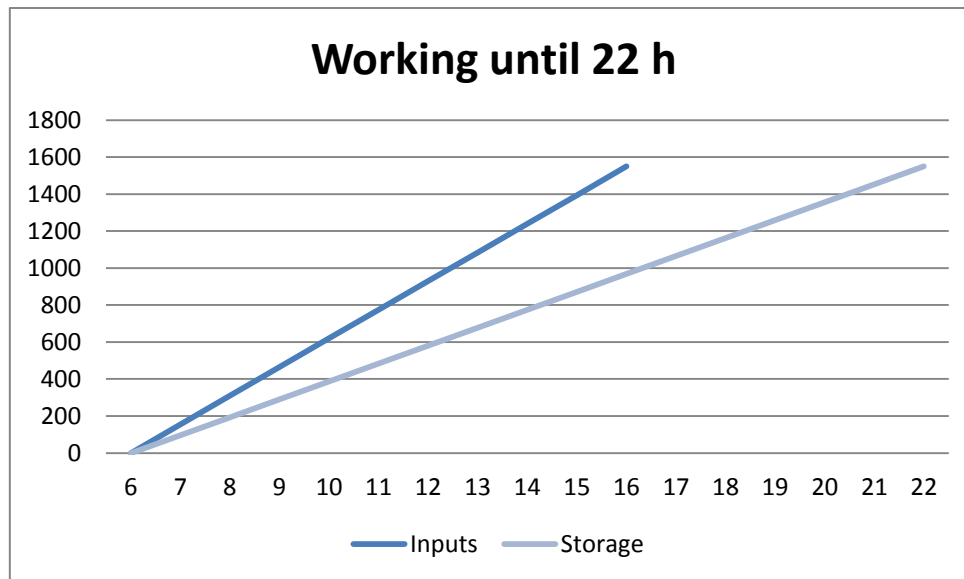
In this way, for the dimensioning of the entry area, it must taking into account that this area will put up all pallets that will be located into silo in one day.

Moreover, it is assumed that takes 3 minutes of average for worker placing the pallet in the silo. This time includes the loading pallet in the fork-lift, transport to the silo, lifting forks and placing the pallet on the shelf, lowers the forks back to ground level and transport the fork-lift to the ticket area again. Therefore, workers can put 20 pallets per hour of work:

$$\frac{1 \text{ pallet}}{3 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hour}} = \frac{20 \text{ pallets}}{\text{hour}}$$

To assess which hypothesis is more convenient, is calculated the number of workers necessary and the space occupied by the accumulated pallets.

- **Scenario 1: The workers work from 6 h to 22 h**



Graphic 2. Inputs (from 6 h to 16 h) and storage in silo (from 6 h to 22 h)

The line "Inputs" corresponds to the pallets that are bringing trucks to the warehouse daily, from 6 am to 16h. The pallets arrive at a rate of 155 pallets / hour, reaching 1550 pallets daily at 16h.

The line "Storage" corresponds to the pallets that must be placed in the silo assuming workers working until 22h. The slope of this line determines the rate of work. In order to have the entry zone free of pallets at 22 h, workers should work at a rate of 96.875 pallets / hour. Finally, as the employees work at a rate of 20 pallets / hour, it takes a total of 5 workers.

To calculate the number of pallets that will be accumulating throughout the day in the reception area, the rate of storage must be recalculate, this time with the actual slope (5 operators, 100 pallets / hour) and no longer theoretical (96.875 pallets / hour).

The following table lists shows by hours the following information: arrivals pallets, the theoretical storage, real storage and accumulated pallets. These are calculated from the subtraction between arrivals and real storage. The accumulation, as is logical, will peak at 16h.

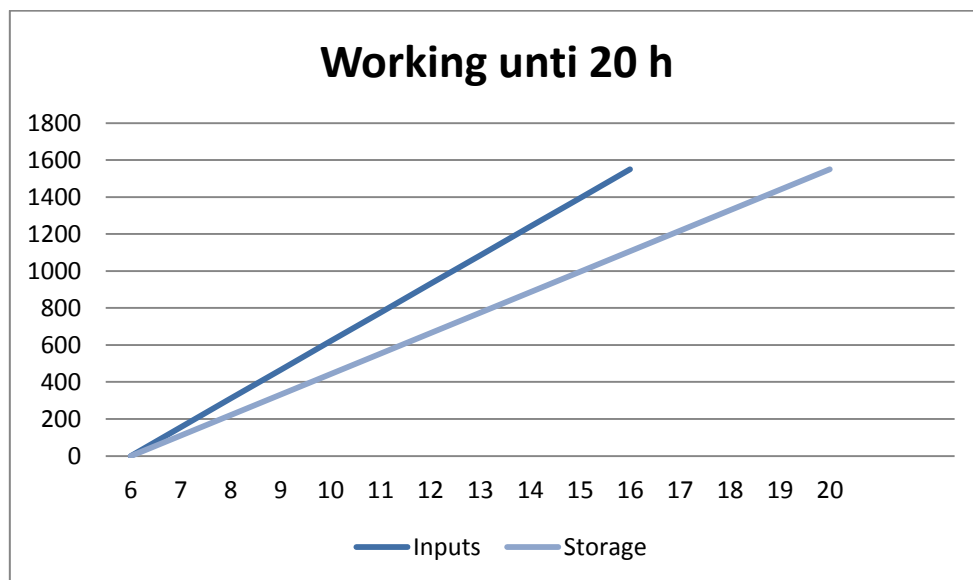
Time	Truks Inputs	Theoretical storage	Real storage	Pallets
6	0	0	0	0
7	155	96,88	100	55
8	310	193,75	200	110
9	465	290,63	300	165
10	620	387,5	400	220
11	775	484,38	500	275
12	930	581,25	600	330
13	1085	678,13	700	385
14	1240	775	800	440
15	1395	871,88	900	495
16	1550	968,75	1000	550
17		1065,63	1100	450
18		1162,5	1200	350
19		1259,38	1300	250
20		1356,25	1400	150
21		1453,13	1500	50
22		1550		

Table 15. Data from the scenario 1

Finally, for Hypothesis 1, corresponding to a working day from 6am to 22h, 5 workers would be needed and 550 pallets would be accumulated in the reception area.

- **Scenario 2: The workers work from 6 h to 20 h**

The procedure is the same as for Hypothesis 1.



Graphic 3. Inputs (from 6 h to 16 h) and storage in silo (from 6 h to 20 h)

The line "Inputs" As in Scenario 1.

The line "storage" which corresponds to the pallets that must be placed into the silo assuming that the operators work only until 20 h. The theoretical slope of this line 110,71 pallets / hour, 6 operators will be needed. These then work at a real rate of 120 pallets / hour.

The following table shows by hours the following information: arrivals pallets, the theoretical storage, real storage and accumulated pallets:

Time	Truks Inputs	Theoretical storage	Real storage	Pallets
6	0	0	0	0
7	155	110,71	120	35
8	310	221,43	240	70
9	465	332,14	360	105
10	620	442,86	480	140
11	775	553,57	600	175
12	930	664,29	720	210
13	1085	775	840	245
14	1240	885,71	960	280
15	1395	996,43	1080	315
16	1550	1107,14	1200	350
17		1217,86	1320	230
18		1328,57	1440	110
19		1439,29	1560	
20		1550		

Table16. Data from scenario 2

Finally, for Scenario 2, corresponding to a working day from 6 h to 20 h, 6 workers would be needed and 350 pallets will be accumulated in the reception area.

Reception area sizing

Due to in Scenario 1 the number of pallets that will accumulate in the reception area is very large (550 versus 350), this is the main reason why Scenario 2 is chosen, in which six workers work from 6am to 20pm.

In order to optimize space, 350 pallets will accumulate in two heights. Therefore, they occupy an area of 146,16 m². To allow the machine to maneuver correctly and that the operators do not interfere, the surface of the reception area must be at least equal to three times the area occupied, so must be greater or equal to 438,48 m².

Reception area	
Maximum pallets accumulated	350
Levels	2
Pallets per level	175
Occupied area (m ²)	146,16
Real requirements (m ²)	438,48

Table 17. Size of the reception area

Expedition Area

For the sizing of the departure area, it proceeds similarly as for the reception area.

The volume of output pallet store will vary throughout the year and reach the peak in November, when 2170 departures / day are expedited. It must size the departure area for this maximum value. However we must note that the number of the workers depends on seasonality.

The output of the pallets is made from 10h to 22h. Assuming that the outputs are uniformly distributed:

$$\frac{\text{Outputs}}{\text{Hour}} = \frac{\text{Outputs/day}}{\text{Hours/day}} = \frac{2170}{12} \approx 180,83 \text{ Outputs/h}$$

Therefore, trucks must carry 180.83 pallets / hour, from 10h to 22h.

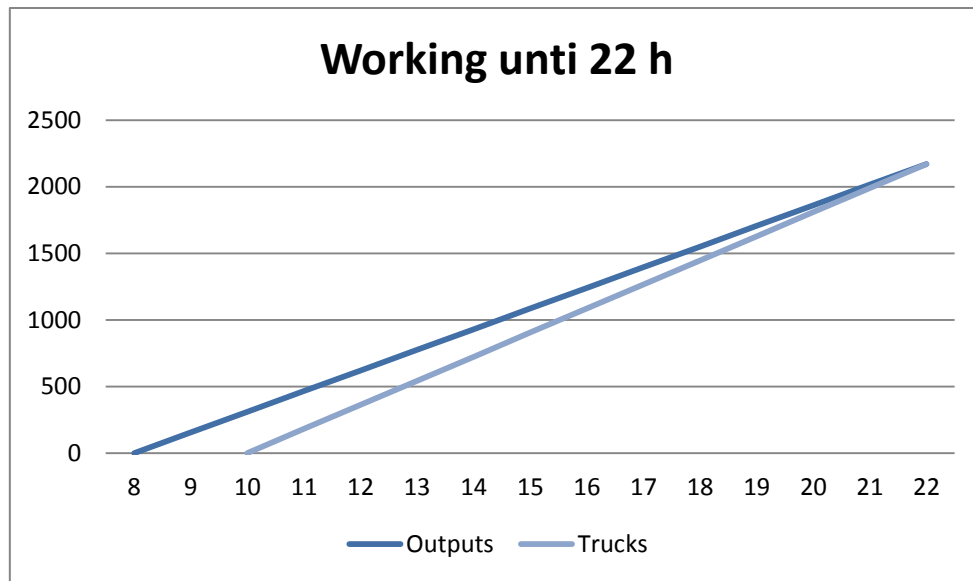
For the expedition area, the following two assumptions are made:

- **Scenario 3: Employees work from 8 h to 22 h**
- **Scenario 4: Employees work from 8 h to 20 h**

It is assumed that workers need on average 3 minutes to collect the pallet from the silo and take it to the expedition area. Therefore, they can carry 20 pallets / hour.

As was done in the reception zone, and to be able to assess which hypothesis is most suitable, it will be calculated the number of workers necessary and the space occupied by the accumulated pallets.

- **Scenario 3: Employees work from 8 h to 22 h**



Graphic 4. Expedition of the pallets (from 10 to 22 h) and placing the pallets in the expedition area (from 8 to 22)

The line "Trucks" corresponds to the pallets that trucks take daily from the warehouse, from 10h to 22h. The pallets go out at a rate of 180,83 pallets / hour, reaching the 2170 pallets daily at 22h.

The line "Outputs" corresponds to the pallets that must be taken at the silo and then placed in the expedition area to proceed to dispatch assuming that workers work until 22h. The slope of this line determines the pace of work of the employees, which means how fast the pallets must be bringing to the expedition area. So workers should work at a rate of 155 pallets / hour. A total of 8 operators, who work at a real rate of 160 pallets / hour, will be needed in that case.

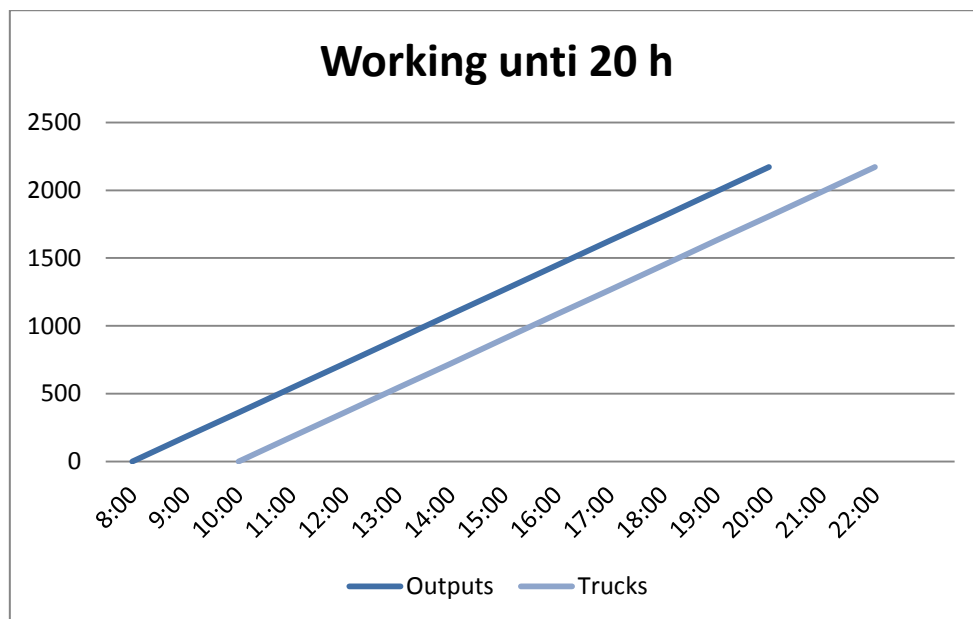
The following table lists shows by hours the following data: pallets outputs, the outputs of theoretical silo, silo real outputs and pallets accumulated in the dispatch area. These are calculated from the subtraction between the outputs of the actual silo and pallet outputs. The peak hour will be at 10 h, when trucks starting to work.

Time	Outputs	Theoretical outputs	Real outputs	Accumulated pallets
8		0	0	
9		155	160	160
10	0	310	320	320
11	180,83	465	480	299,17
12	361,67	620	640	278,33
13	542,5	775	800	257,5
14	723,33	930	960	236,67
15	904,17	1085	1120	215,83
16	1085	1240	1280	195
17	1265,83	1395	1440	174,17
18	1446,67	1550	1600	153,33
19	1627,5	1705	1760	132,5
20	1808,33	1860	1920	111,67
21	1989,17	2015	2080	90,83
22	2170	2170	2240	

Table 18. Data from scenario 3

Finally, for Scenario 3, corresponding to a working day from 10h to 22h, 8 workers will be needed and a maximum of 320 pallets will be accumulated in the expedition area.

- **Scenario 4: The workers work from 8 h to 20 h**



Graphic 5. Expedition of the pallets (from 10 to 22 h) and placing the pallets in the expedition area (from 8 to 22)

The line "Trucks" corresponds to the pallets that trucks take daily from the warehouse, from 10h to 22h.

The line "Outputs", corresponds to the pallets that are placed in the expedition area, assuming that employees work until 20 h. Being the theoretical slope of this line equals to 180,83 pallets / hour, will be taken in total 9 workers. The real rate work will be 180 pallets / hour.

The following table lists shows by hours the following data: pallets outputs, the outputs of theoretical silo, silo real outputs and pallets accumulated in the dispatch area.

Time	Outputs	Theoretical outputs	Real outputs	Accumulated pallets
8:00		0	0	
9:00		181	180	180
10:00	0	362	360	360
11:00	181	543	540	359
12:00	362	723	720	358
13:00	543	904	900	358
14:00	723	1085	1080	357
15:00	904	1266	1260	356
16:00	1085	1447	1440	355
17:00	1266	1628	1620	354
18:00	1447	1808	1800	353
19:00	1628	1989	1980	353
20:00	1808	2170	2160	352
20:03	1818		2170	352
21:00	1989			181
22:00	2170			0

Table 19. Data from scenario 4

Finally, for Scenario 4, corresponding to a working day from 10 h to 20 h, 9 workers will be needed and a maximum of 360 pallets will be accumulated in the expedition area.

Expedition area sizing

Scenario 3 will be chosen because the pallet number which become to accumulate in the dispatch area and the number of operators required are lower than in the case of Scenario 4. Therefore, 8 operators will be working from 10 h to 22 h.

In order to optimize the space, 320 pallets will accumulate in two heights of 160 pallets each. Therefore they occupy an area of 133.63 m². To allow the machinery to maneuver properly and that operators do not bother each other, the surface of the expedition area must be at least equal to three times the area occupied by the pallets, that is greater than or equal to 400, 90 m².

Expedition area	
Maximun pallets accumulated	320
Levels	2
Pallets per level	160
Ocuped area (m ²)	133,63
Real requirements (m ²)	400,90

Table 20. Size of the expedition area

DOCKS

Number of docks

In order to attend correctly the arrival and outputs pallets per day, a number of docks will be established. This amount is calculated based on the number of trucks arriving per hour to the reception area and the expedition area. The calculation of the number of docks for the month with the highest number of inputs and the month with the highest number of outputs is performed.

Reception area

Maximum input of pallets / day produced in the 12 months of the year is 1550 pallets (day). 10 hours will be considered because the pallets can be delivered from 6:00 to 16:00 h.

$$\frac{1550 \text{ pallets}}{1 \text{ day}} \times \frac{1 \text{ day}}{10 \text{ hours}} = 155 \text{ pallets/hour}$$

The capacity of each truck container is 32 pallets. Therefore every hour five trucks arrive.

$$\frac{155 \text{ pallets/h}}{32 \text{ pallets/truck}} = 4,85 \text{ truck/h}$$

Assuming a uniform distribution in arrivals, every 12 minutes will be arrived a truck, it is going to be parked at the dock until the download will be completed. The download time depends on the handling system used. There are two options that have been considered for the realization of such activity:

- Manual fork lift: 45 minutes / unloading truck.
- Fork lift: 25 minutes / unloading truck.

It has chosen the first option, used manual fork lift, namely two, thereby reducing download time into 25 minutes. The reason for this decision is to reduce the number of fork-lifts. In addition the budget will be reduced (150 € vs. 7,000 €).

The simulation method is used to calculate the number of docks. In the next table each of the events that change the state of the system, in this case shown, refers to when a dock is occupied or free. The time when the system change is every 12 minutes (when a truck arrives) and after 25 minutes from the entrance of each truck, it goes. The box "truck arrivals" indicates the time t in which a truck arrival occurs. When this input occurs there must be a

dock always available where it can download. The time in parentheses refers to the exact time when the dock is going to be free and another truck can go in.

Time	Truck arrivals	Queue	Dock 1	Dock 2	Dock 3	Exit
0	1		1 (25 min)			
12	2		1 (25 min)	2 (37 min)		
24	3		1 (25 min)	2 (37 min)	3(49min)	
25				2 (37 min)	3(49min)	1
36	4		4 (61 min)	2 (37 min)	3(49min)	
37			4 (61 min)		3(49min)	2
48	5		4 (61 min)	5(73min)	3(49min)	
49			4 (61 min)	5(73min)		3
60	6		4 (61 min)	5(73min)	6(85min)	
61				5(73min)	6(85min)	4
72	7		7(97min)	5(73min)	6(85min)	
73			7(97min)		6(85min)	5
84	8		7(97min)	8(109min)	6(85min)	
85			7(97min)	8(109min)		6
96	9		7(97min)	8(109min)	9(121min)	
97				8(109min)	9(121min)	7
108	10		10(133min)	8(109min)	9(121min)	
109			10(133min)		9(121min)	8
120	11		10(133min)	11(145min)	9(121min)	

Table 21. Simulation for entrance docks

The simulation was performed for 2 hours. In that interval time can already see that the inputs and outputs of trucks follow a cyclical function. Therefore it is not necessary more than three docks for 8 hours. Anyway, it has decided to add an extra dock to the 3 obtained above, in case one of the trucks is delayed or advanced in your schedule.

Expedition area

To size the docks in this area the same process is performed as for the reception area. In this case the maximum output per month amounts to 2170 pallets per day. In this case outputs trucks are performed for 12 hours in a day.

$$\frac{2170 \text{ pallets}}{1 \text{ day}} \times \frac{1 \text{ day}}{12 \text{ hours}} = 180,8 \text{ pallets/h}$$

$$\frac{181 \text{ pallets/h}}{32 \text{ pallets/truck}} = 5,65 \text{ trucks/h}$$

$$\frac{60 \text{ min}}{5,65 \text{ truck/h}} = 10,61 \frac{\text{min}}{\text{exit}} \text{ truck}$$

Employees handling systems for loading the truck are the same as for unloading, 2 manual fork lifts will be used, the loading operation requires 25 minutes to be completed.

In order to calculate the number of docks in this area a simulation table will be used. Every 10,61 minutes (arrival of truck) and every 25 minutes after the arrival of each truck the system changes.

Time	Truck exits	Queue	Dock 1	Dock 2	Dock 3	Exit
0	1		1(25min)			
10,6	2		1(25min)	2(35,6min)		
21,2	3		1(25min)	2(35,6min)	3(46,2min)	
25				2(35,6min)	3(46,2min)	1
31,8	4		4(56,8min)	2(35,6min)	3(46,2min)	
35,6			4(56,8min)		3(46,2min)	2
42,4	5		4(56,8min)	5(67,4min)	3(46,2min)	
46,2			4(56,8min)	5(67,4min)		3
53	6		4(56,8min)	5(67,4min)	5(78min)	
56,8				5(67,4min)	5(78min)	4

Table 22. Simulation for exits dock

Therefore, as the table shows 3 docks will be necessary. Finally, in order to be covered against schedule changes, reparations, etc. other dock will be added.

Required operators

Area store inputs and outputs will need:

- Operators to handle the merchandise silo to the dispatch area or reception area to the silo.
- Operators dedicated exclusively to the loading and unloading trucks.

For this calculation we used the results obtained through simulation. The amount of operating docks directly determines the workforce needed: as shown in the simulation tables, the maximum number of busy docks simultaneously for reception and shipment is always equal to 3. Two operators will be needed for each truck, as the maximum number of trucks is 3 in each both cases, the total amount of operators will be 6. Finally, considering both areas, 12 workers in total will be needed.

CORRIDORS

The corridors are two ways trying to avoid traffic jams and an excessive amount of fork lifts circulating in the same area. This decision is given because the number of inputs and outputs per day are high, so this store has a great flow and high rotation and fork-lifts can be disturbing each other.



The dimensions of each corridor is 4,3 m, where, 2,8 m are used for the fork lift in order to be positioned longitudinally for loading / unloading pallets. The remaining 1,5 m is the width of the fork lift, so if one is performing the loading / unloading in one of the lanes, the other can pass without having to wait for it to complete its activity.

These corridors explained above, refer to the longitudinal aisles of the warehouse, but apart from these also exist transverse corridors. To calculate the size of these corridors, 4 m, has been considered the turning radius of the fork lift used. The turning radius is 1,6 m for the chosen fork lift. Being two-way corridors has decided multiplying that value by 2, so two fork lifts will be able to turn at the same time without interruption.

The outer corridors of shelves at the ends of store only have one direction, so the width will be reduced to 2,8 m (size necessary for a fork lift to do the loading and unloading operation from the shelf).

LAYOUT

Silo

After calculating the dimensions of the shelves and corridors the silo sizes are obtained. This will have 102,95 m wide and 128,7 m long.

Distribution

In the next plans are exposed modulus of flammable goods, other nonflammable and layout plan of the installation.

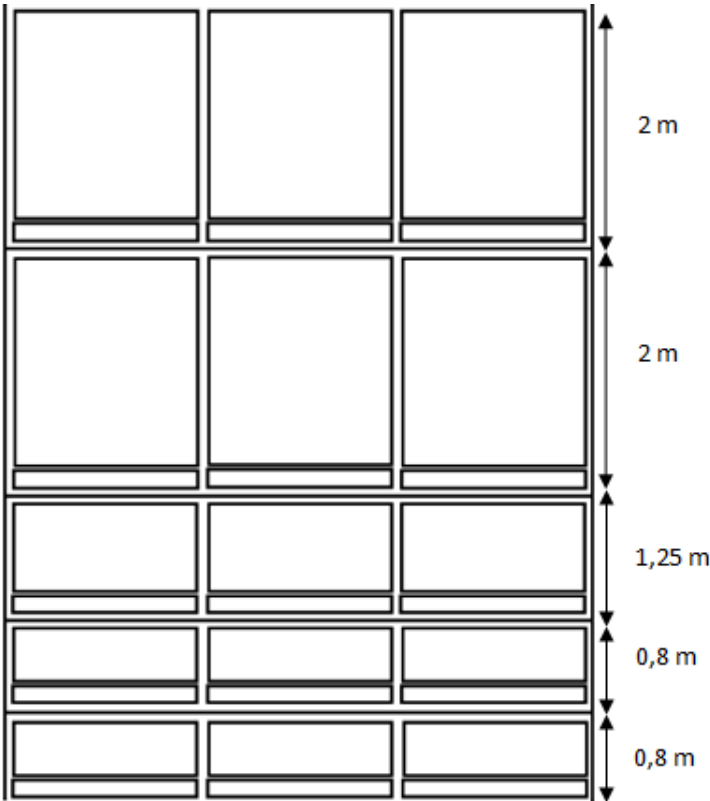


Image 3. Flammable shelves

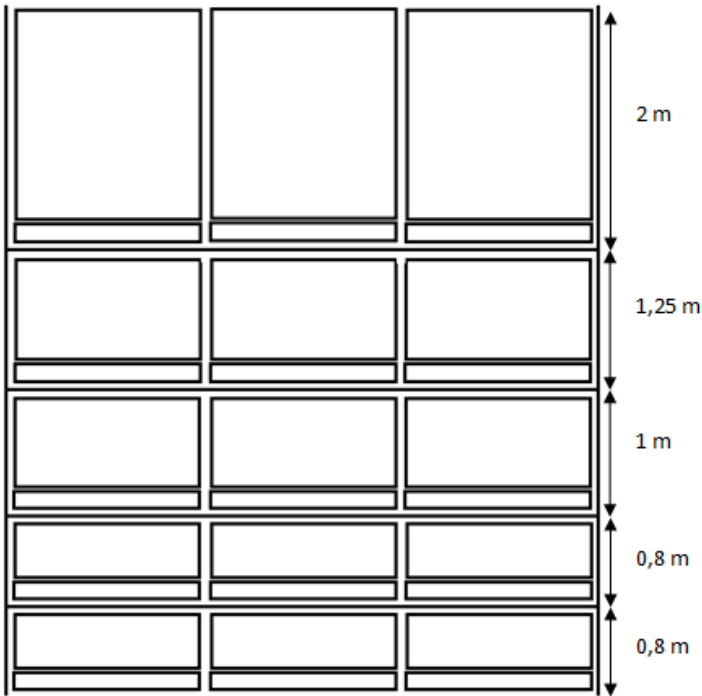


Image 4 Nonflammable shelves

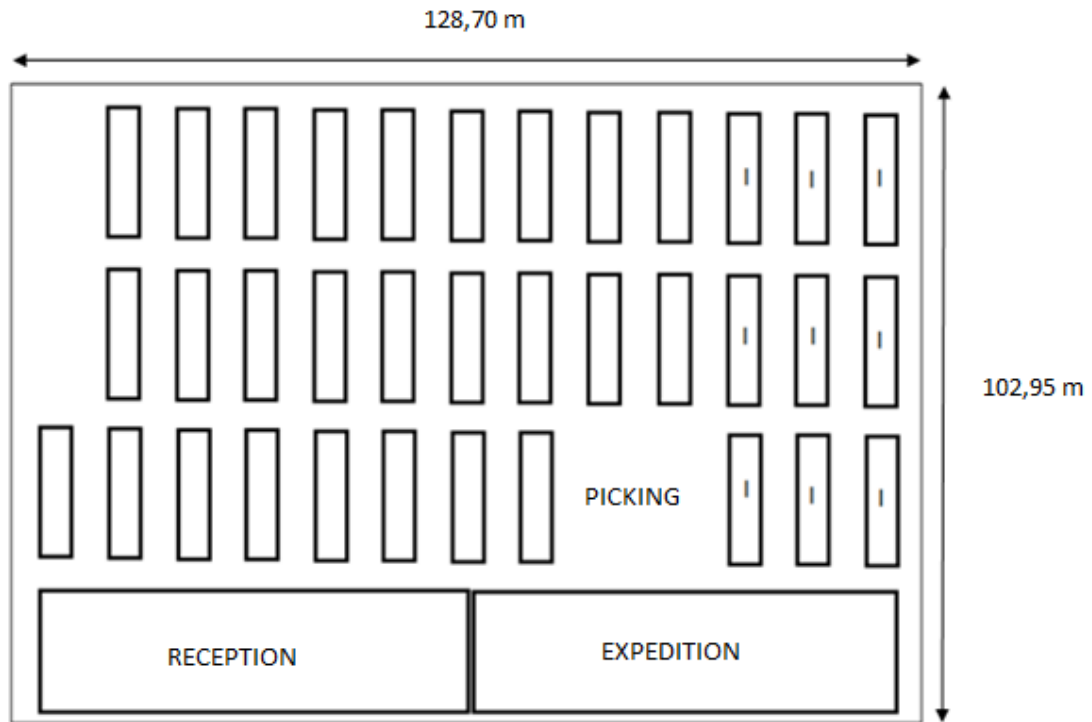


Image 5. Layout

FORK LIFT

Due to the maximum height in the warehouse is the 6,45 m and the pallets are not heavy enough.

Finally the decided fork lift corresponds with a retractable fork lift. This type of fork lift is used in height of 8-10 m and for products not excessively heavy.



Image 6. Retractable fork lift

In order to carry out the loading and out loading operation in the expedition and reception area other kind of fork lifts will be used.



Image 7. Manual fork lift

PICKING AREA

Some customers have orders of products with different quantities of goods. For this reason it has to be designed a picking area.

According to the data product 4 does not required picking, 30% of pallets 1, 40% of pallets 2 and 3.

The picking area is used to prepare orders for products from different pallet output orders. For this reason the position of the picking area will be situated in front of the expedition area of the warehouse. The maximum output per day is 2170 pallets / day, and the percentages of the different pallets are:

Kind of pallet	Percentage of output	Max outputs pallets	Number of pallets for picking
1	38,71%	840	252
2	19,35%	420	168
3	16,13%	350	140
4	25,81%	560	0
Total		2170	560

Table 23. Pallets for picking

The total amount of pallets for picking results 560 pallets / day, operators picking work for 12 hours, from 8 h to 20 h, 47 pallets / hour will be picked.

The inputs in the picking area must be constant, so finally it has decided to retain in the picking area a minimum stock of pallets of each type, a total amount of 32 pallets, without stack up.

The sizing of the picking area is calculated based on the sizes of the 32 pallets:

$$A = \text{pallets} * \text{width pallet} * \text{length pallet}$$

$$A = 32 * 0.8 * 1.2 = 30,7 \text{ m}^2$$

Furthermore, it should be taken into account that for the correct perform of the operator activities this surface will be multiply 4 times, the final result is 122,8 m².

It is not absolutely necessary to have a specific area of picking for the preparation of orders, this work could be done in the same corridors. However, in this case the better option is doing this operation in a separated area due to the large number of movements that are in store corridors.

REQUIRED OPERATORS

As the calculus show before that for a reception area 6 workers will be necessary, for expedition area 8 workers will be necessary and for load the trucks in reception and in expedition 6 workers will be required in both places, other 2 for the picking area and other 2 for the maintenance of the warehouse.

In offices 2 workers will be required as well, so the total amount of operators will be $6 + 8 + 6 + 6 + 2 + 2 + 2 = 32$ workers.

STRUCTURAL FEATURES

As it has been learned from other similar projects, such structures can be carried out in many possible ways, in situ concrete structure, prefabricated structures, welded or bolted metal structure, mixed structure, etc.

Finally taking into account the economical factor as a most important factor a concrete structure in situ will be chosen, foundations will consist on concrete basements under each pillar, the beams and the walls will be made with prefabricated concrete and will be mounted directly on site. The superior enclosure shall be composed of a metal structure with form of saw-tooth which will combine waterproof opaque enclosure in its inclined parts and translucent material in its vertical sides trying to take advantage of the entrance of the sun and thus achieve a reduction in the electric consumption.

Therefore the final dimensions of the warehouse will be at the base 147 x 109 m and 11,5 m in height. The measures base have been taken into account those obtained in the "Lay out" and the pillars needed to support the structure section has also been taken into account an area for offices, locker rooms and other area to recharge the batteries of the fork lifts. The

minimum height of the ship obtained was 8,9 therefore the height of the warehouse will be 10 m, the final height of the warehouse will be 11,5 in the highest points, due to the tooth saw shaped of the roof.

The foundation will be held by individual concrete basement, the rest of the surface of the store will be composed of reinforced concrete flooring of 30 cm thick to prolong the life of the structure and increase the wear resistance which will be subjected.

The goods are not too heavy, but even so the ground will be under high wear, the risk of puncturing also must be taken into account, lifting machines of great weight that distribute it only in four small footholds, shelves that concentrate the load in a very small area. Therefore finally reinforced concrete flooring of 30 cm thick will be placed.

Store outside pavement will consist of a layer of cleaning concrete HS-20, 15 cm thick and a surface layer of 7 cm composed of bituminous material. This composition of soil is very common when the percentage of heavy vehicles passing through the facilities will be high.

The facilities also will be equipped with full lighting system; fluorescent tubes will be distributed throughout the top of the storage, above each aisle and the expedition and reception area.

Also it takes into account the installation of a anti fire pipes network on the top of the structure with irrigation hydrants every 2 m.

The Spanish law also requires implementing a personnel hygiene facility with toilets, sinks and showers.

In another area of the warehouse an office, where administrative staff work will be installed.

CONCRETE BASEMENT

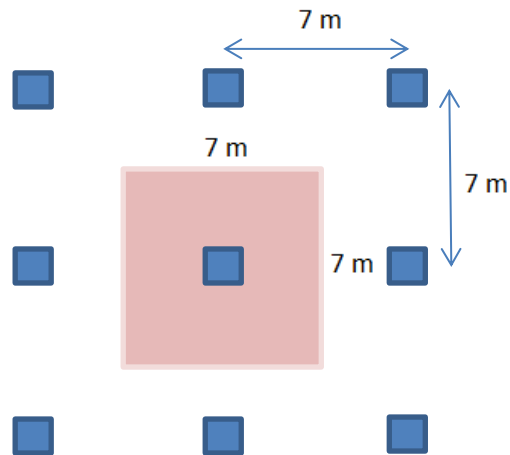
To perform the calculation of the Spanish foundation will be follow the EHE - 08 regulations, a number of simplifications will be made when calculating the structure:

- A single type of concrete basement will be assumed, for this the worst concrete basement will be calculated and the same type will be installed throughout the structure, this will increment the safety.
- Will be considered 0 for the shear strength (Q).
- The assembly of the concrete basements will be made with the minimum recommended by regulations.

Knowing that the weight of the deck is $2.77 \text{ T} / \text{m}^2$, the higher tax area will have to endure the worst pillar will be $7 \times 7 \text{ m}$ and the weight of the concrete is $2,5 \text{ T} / \text{m}^3$ and pillars have dimensions of $0.4 \times 0.4 \times 10 \text{ m}$ will be obtained:

$$7 \cdot 7 \cdot 2,77 + 2,5 \cdot 0,4 \cdot 0,4 \cdot 10 = 139,73 \approx 140 \text{ T/Pillar}$$

Highest load area per pillar:

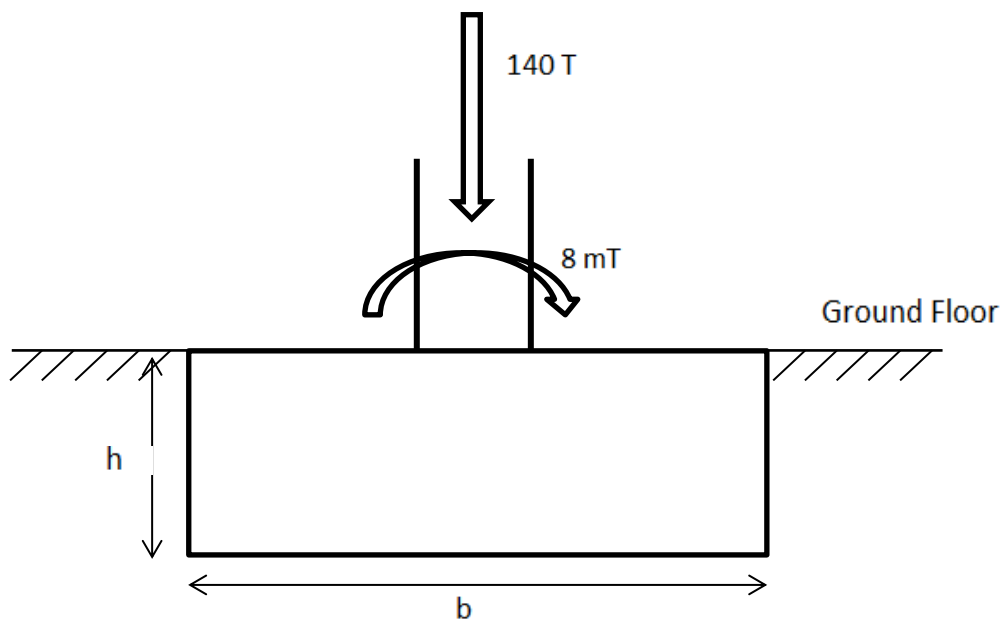


Therefore all concrete basements will be calculated for this load.

The bending moment will be 8mT

The admissible tension of the ground will be $\sigma = 2,5 \text{ kg/cm}^2$

Concrete = H-250



Due to the bending moment does not exceed 10% of 140 (14 mT), squared concrete basement will be design. Trying to simplify the calculations the single loads of the concrete basements will not be considered:

$$b = \sqrt{\frac{140}{25}} = 2,36 \approx 2,50 \text{ m}$$

$$h = \frac{b}{3} = 0,78 \approx 0,80 \text{ m}$$

Therefore the single load of the concrete basement will be:

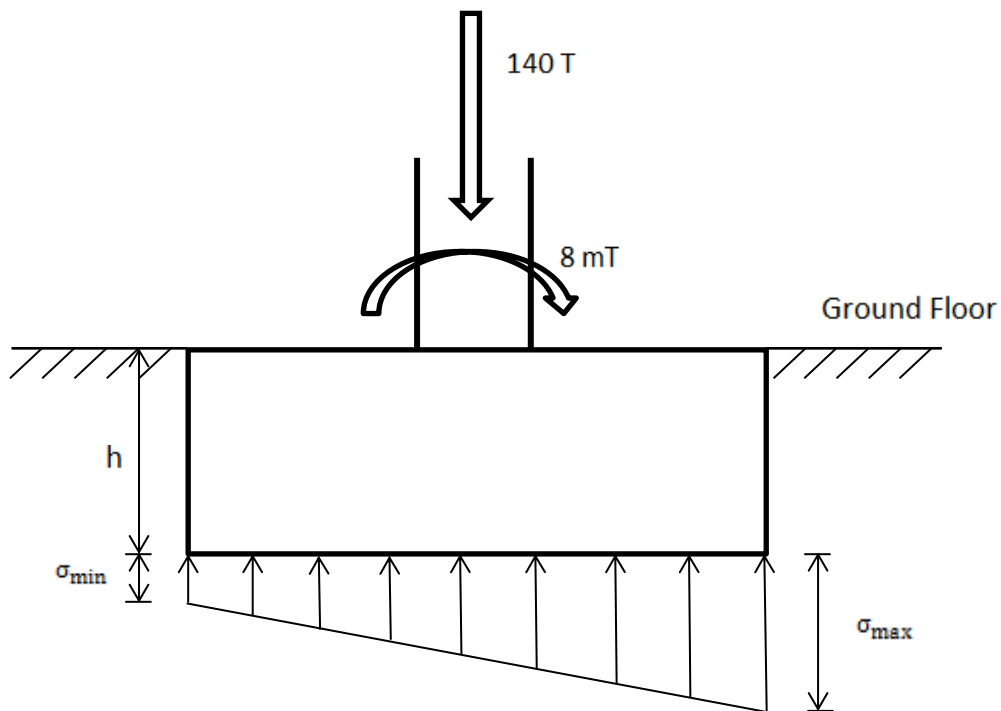
$$W_c = 2,50 \cdot 2,50 \cdot 0,80 \cdot 2,50 = 12,50 \text{ T}$$

$$N_t = 140 + 12,50 = 152,50 \text{ T}$$

Eccentricity:

$$e = \frac{M}{N_t} = \frac{8}{152,50} = 0,052 < \frac{b}{6}$$

Due to that, the resultant will be applied in the central core so the ground will respond as a trapeze.



$\sigma = \frac{Nt}{b^2} \left(1 \pm \frac{6 \cdot e}{b} \right)$; replacing values:

$$\sigma = \frac{152,50}{2,50^2} \left(1 \pm \frac{6 \cdot 0,052}{2,50} \right) \left\{ \begin{array}{l} \sigma_{max} = 27,44 \frac{T}{m^2} < 1,25 \sigma_{adm} \\ \sigma_{med} = 24,40 \frac{T}{m^2} < \sigma_{adm} \\ \sigma_{min} = 21,35 \frac{T}{m^2} > 0 \end{array} \right.$$

The sinking conditions are met, therefore the concrete basement is valid.

FLEXION CALCULATIONS

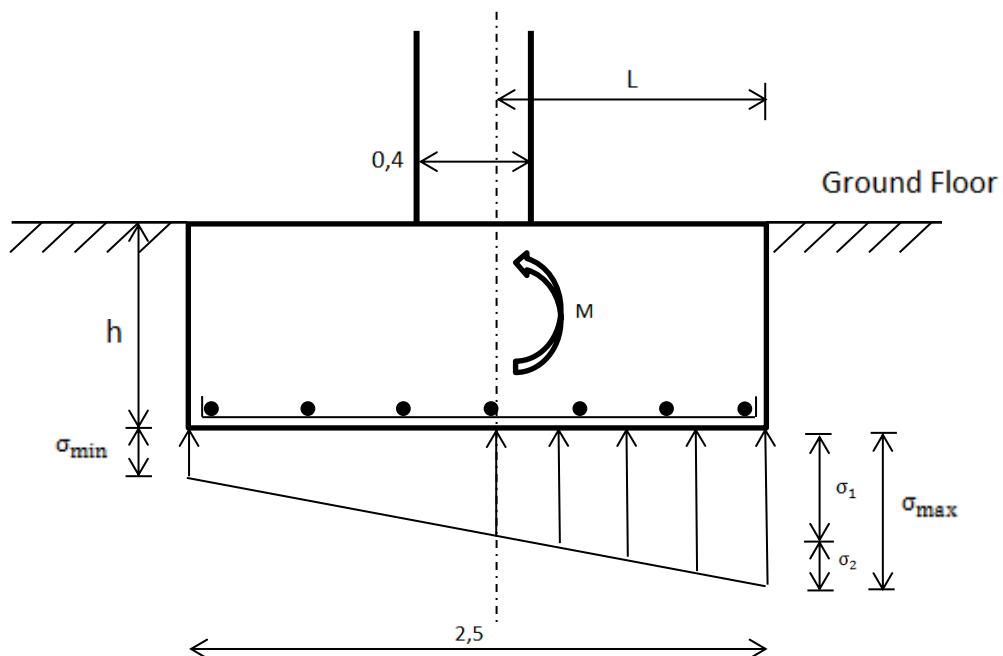
Without taking into account the single load of the concrete basement the tensions in it will be:

$$e = \frac{M}{N} = \frac{8}{140} = 0,057$$

$$\sigma = \frac{140}{2,50^2} \left(1 \pm \frac{6 \cdot 0,057}{2,50} \right)$$

$$\sigma_{\max} = 25,46 \frac{T}{m^2}$$

$$\sigma_{\min} = 19,33 \frac{T}{m^2}$$



$$L = \frac{2,50 - 0,40}{2} = 0,15 \cdot 0,40 = 1,11 \text{ m}$$

$$\sigma_1 = 19,33 + \frac{6,13 \cdot 1,39}{2,50} = 22,74 \text{ T/m}^2$$

$$\sigma_2 = \sigma_{\max} - \sigma_1 = 2,72 \text{ T/m}^2$$

The moment will be:

$$M = \frac{1}{6} \cdot b \cdot L^2 \cdot (3 \cdot \sigma_1 + 2 \cdot \sigma_2) = \frac{1}{6} \cdot 2,50 \cdot 1,11^2 \cdot (3 \cdot 22,74 + 2 \cdot 2,72) = 37,81 \text{ mT}$$

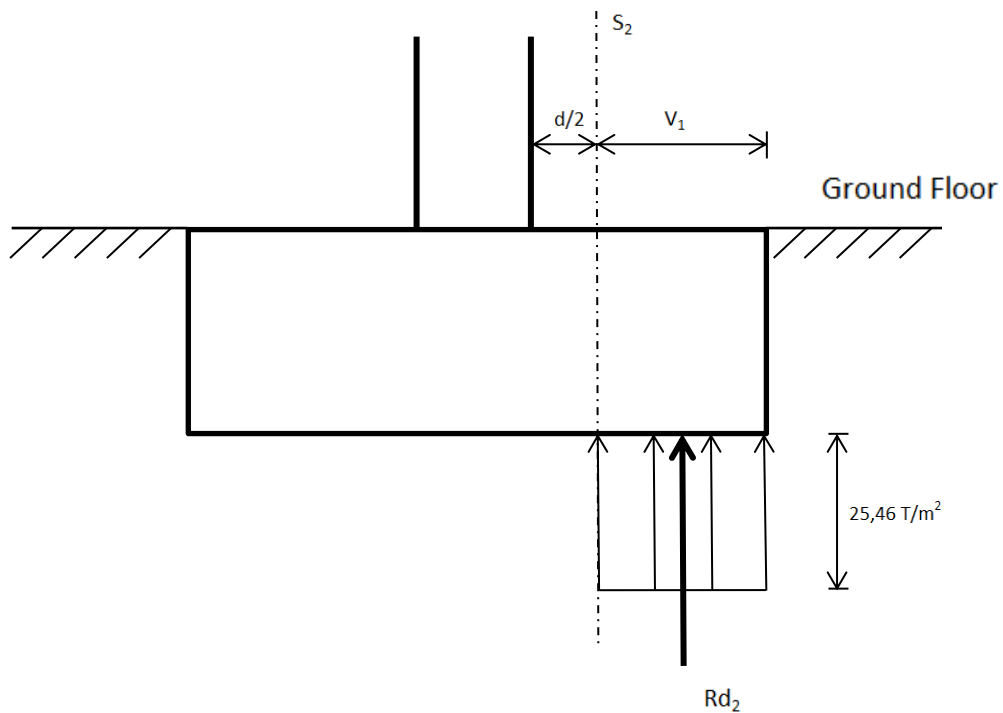
The calculus moment will be taking into account the security factor:

$$M_d = 37,81 \cdot 1,6 = 60,50 \text{ mT}$$

This moment should be apply for a section of $2,50 \times 0,80 \text{ m}^2$ and concrete H-250.

For this bending moment the Spanish normative recommend, as minimum reinforced, put in the down part a square grill with round iron bars of 18 mm of diameter.

SHEAR STRENGTH AND PUNCHING SHEAR TESTING



In order to be safer let us assume that the response of the ground is rectangular and takes value σ_{\max} .

$$d = 0,75m$$

$$\frac{d}{2} = 0,375 m$$

$$b_2 = b' + d = 0,40 + 0,75 = 1,15m$$

$$V_1 = 0,675m; 1,5V_1 = 1,01m$$

$$d_2 = d = 0,75m$$

$$Rd_2 = V_1 \cdot b \cdot \sigma \cdot csec = 0,675 \cdot 2,50 \cdot 25,46 \cdot 1,60 = 68,74 T$$

The resistance of the “window” section will be:

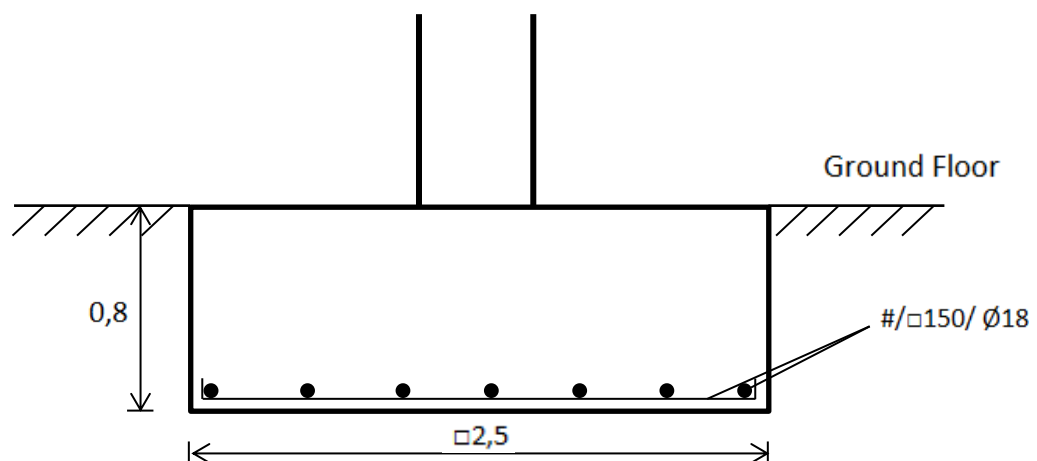
$$Vd_2 = 115 \cdot 75 \cdot \sqrt{\frac{250}{1,5}} = 111,348 T$$

$$Vd_2 > Rd_2$$

Overturning Security:

$$Coef = \frac{\text{stabilizing forces}}{\text{overturning forces}} = \frac{N_1 \cdot b/2}{M} = \frac{152,50 \cdot 1,25}{8} = 23,82$$

Finally this would be the final scheme reinforced concrete basement:



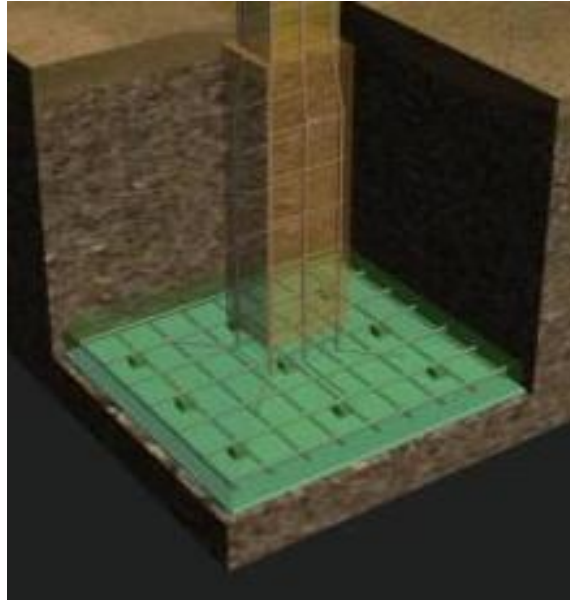


Image 8. Scheme of reinforced

PILLARS

The pillars of the structure will be prefabricated, square morphology with side 0,40 m and a height of 10 m and concrete HA-250. They will be placed on site with a crane. Then similar images will be shown.



Image 9. Assembly of the pillars



Image 10. Prefabricated pillars

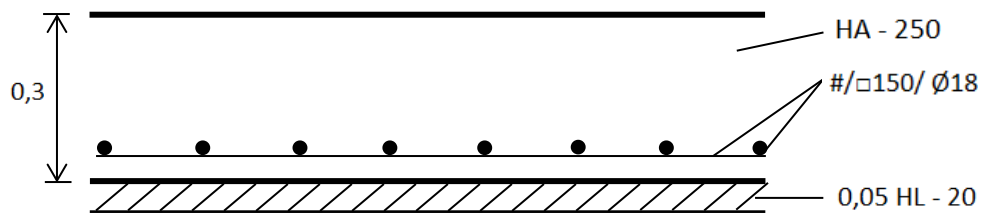


Image 11. Scheme of the union between pillar and the concrete basement

REINFORCED CONCRETE FLOORING

Concrete basement will be together, connected each other's with a reinforced concrete flooring along the entire surface of the warehouse, for execution first layer of 5 cm thickness will extend HL -20 and this the foundation slab have the following characteristics , 30 cm thick, 18 mm square grid every 15 cm. The concrete will be H - 250.

This type of reinforced concrete flooring is very common in this type of construction, as has been learned from other projects.



PAVING SURFACE

The paving surface of the surroundings of the warehouse will be constituted for a layer of concrete HS – 20 of 15 cm thickness and an asphalt layer of 7cm of thickness.

Before execute the paving will be proceeded to compact the existent floor until arise 95 % of compaction in the Proctor essay. The thickness of the compacted surface will be at least of 30 cm. Once this is done will be extended the concrete layer until arise 15 cm, when this operation finish and the concrete had tightened will be spread two layers of 3,5 cm in two different times until arise 7 cm thickness.

Each layer will have 2 % of slope in direction to the scuppers of the installation.



PREFABRICATED BEAMS

The beams of the installation will be prefabricated and installed in situ with the help of a crane, their length will be 7 m and will be support at the end of the pillars. The dimensions of them will be:

A= 20

B=20

C= 40

D=10

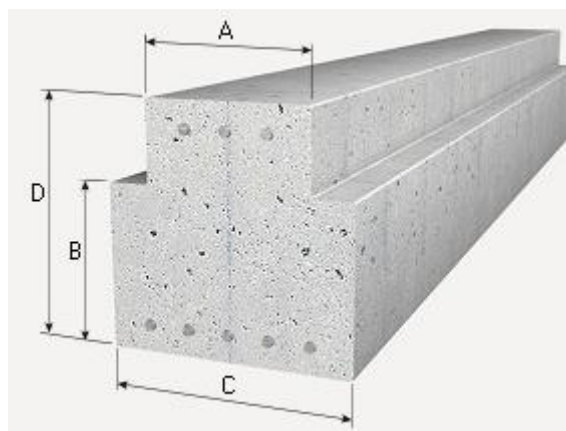


Image12. Dimensions of the beam



Image 13. Prefabricated beam

WALLS

The walls of the warehouse will be prefabricated, they will be installed with the help of a crane, the dimensions of them will be 3,5 x 3,5 m less that the top walls that will be have 3,5 x 3 m. The thickness of these walls will be 20 cm, and will be placed aligned with the outside face of the pillars.



Image 14. Concrete prefabricated walls



Image 15. Concrete prefabricated walls

ROOF

The roof will be a metal structure with form of saw-tooth which will combine waterproof opaque enclosure in its inclined parts and translucent material in its vertical sides trying to take advantage of the entrance of the natural bright and thus achieve a reduction in the electric consumption.

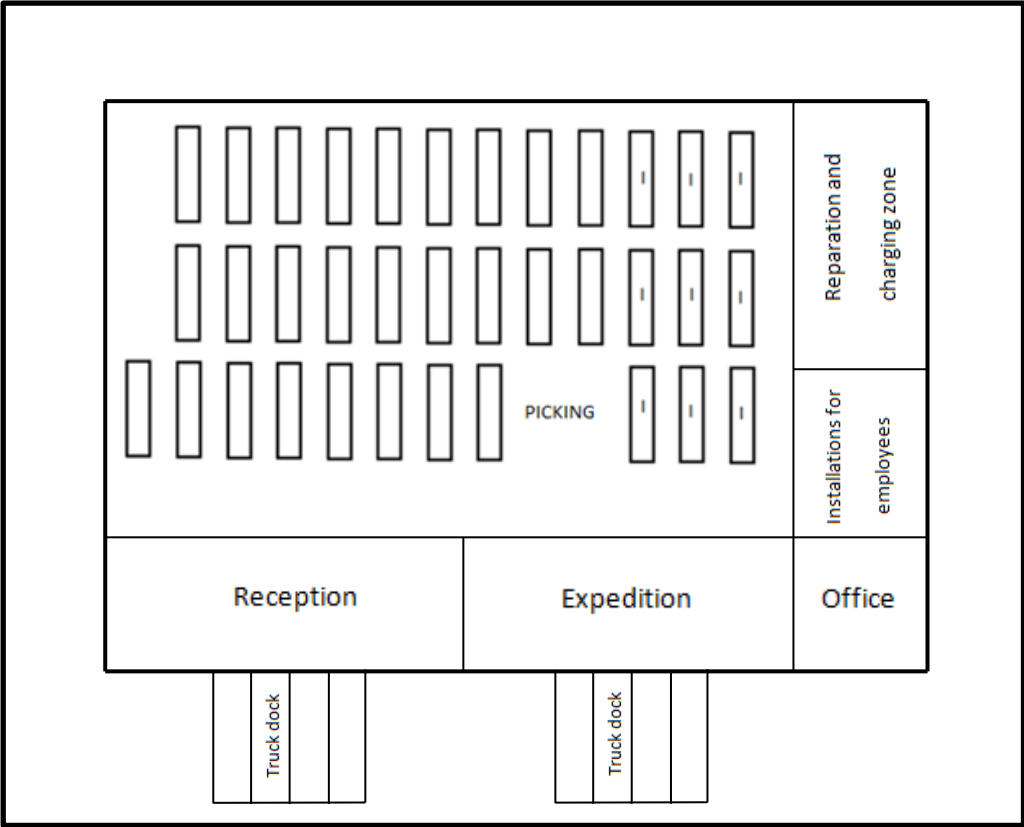


Image 16. Saw-tooth roof



Image 17. Saw-tooth roof

FINAL DESINGN



AUTOMATED WAREHOUSE

GENERAL DESCRIPTION

The automated warehouse is a compact structure formed by the shelves with covers and walls of the store itself. Its main feature is that the shelves are first installed and then the walls and cover. The shelves support loads of merchandise, structural elements, the thrusts of the means of support and external agents, as the force of wind, overload of snow, earthquakes, etc.

Automated warehouses allow using different storage systems: conventional, compact and dynamic gravity, however, to achieve the maximum capacity, the placement of the goods is made under the principle: "empty space". I.e., when a pallet is entered the system assigns the first empty hollow of the corridor and computer memorizes the shelf and position for later access it according to the extraction criteria set out by the store.

The advantages of the automated warehouse are:

- Highest building, only limited by national legislation (35 meters)
- Shorter execution time.
- Ease of future expansion and maximum space optimization
- Varying degrees of automation

DYNAMIC CAPACITY

Dynamic capacity is refer to the quantity of average stock that rote in the warehouse in a determined period. It is calculated as follows:

$$\text{Dynamic Capacity} = \frac{\sum(\text{Inputs or Outputs}) \times 22 \text{ Working days}}{12 \text{ months}}$$

Inputs and outputs are balanced warehouse therefore can be used interchangeably values for each calculation. Thus it is obtained that the value of the dynamic capacity is 33248 pallets.

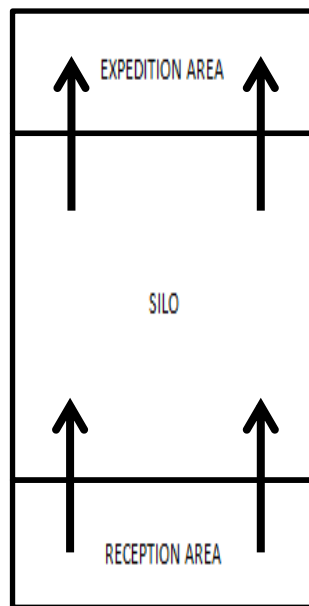
The rotation value could be also calculated through the next expression:

$$\text{Rotation} = \frac{\text{Dynamic Capacity}}{\text{Static Capacity}} = \frac{33248}{23870} = 1,39 \text{ months}$$

This data indicates the time period of time in which theoretically all merchandise contained in the store is renewed.

WAREHOUSE FLOW

The flow of the store will be linear; the reception area will be placed at one end, while the area of expedition will be placed in the other, being the silo in the central part. As shows the next figure:

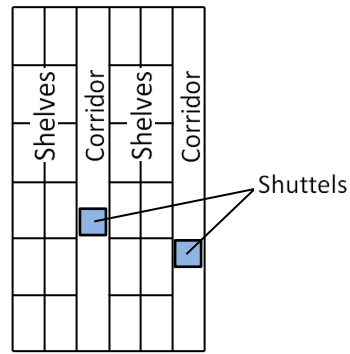


The shelves will have a single depth; therefore every two places will be a corridor which will move the shuttle. The decision of taking this option instead of shelves of double depth is due to the large number of daily movements.

The modules will be composed of gaps of two pallets, the distance between them and the supports will be 10 cm.

All the shelves will be adjustable in height if in the future changes the demand of the warehouse, this will be possible because the supports will have different holes along it, and beams could move depends on the requirements of the warehouse.

Scheme of the corridors:

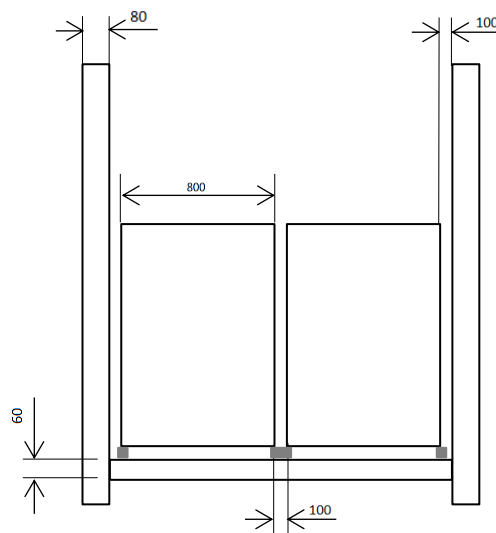


SHELVES

Checking deflection

Then it is checked if deflection beam shelves not exceed the maximum provided by Spanish regulation, which is equal to $L / 500$ (where L is the length of the beam span).

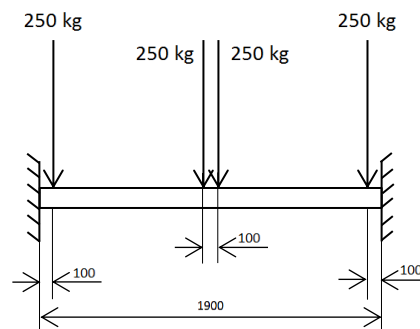
Between support and support, 2 pallets are placed, in 1 row of 2 pallets. Each pallet is placed on two supports and two beams, so that the total load of each pallet is distributed actually in four different points.



Pallets disposed in the shelf (distances in mm)

Each pallet then exerts two points of charge of 250 kg on the crossbar, which means that in total are applied to the spar 2 pairs of symmetrical point loads. As the beams are attached to

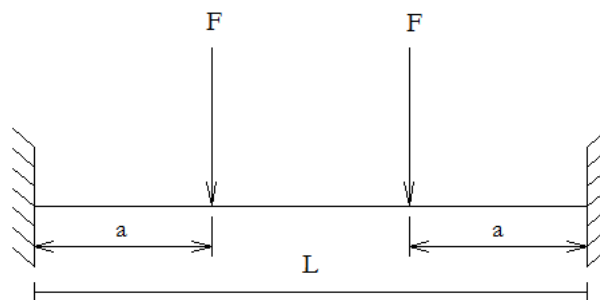
the supports by welding, their behavior can thus assimilate to a fixed-end beam. Therefore, this would be the graphically representation:



Symmetrical loads in the beam (distances in mm)

In the case of the application of 2 point and symmetrical, the maximum deflection (located at the midpoint) is calculated by the following expression:

$$y_{\max} = \frac{Fa^2}{24EI} \times (3L - 4a)$$



Being:

F the applied load

a is the distance between the point of application of force and the end of the beam nearest

L the total length of the beam

E the modulus of elasticity

I the inertia of the beam

The beam can be approximated to a rectangular hollow profile of dimensions 60 * 40 * 2 mm:

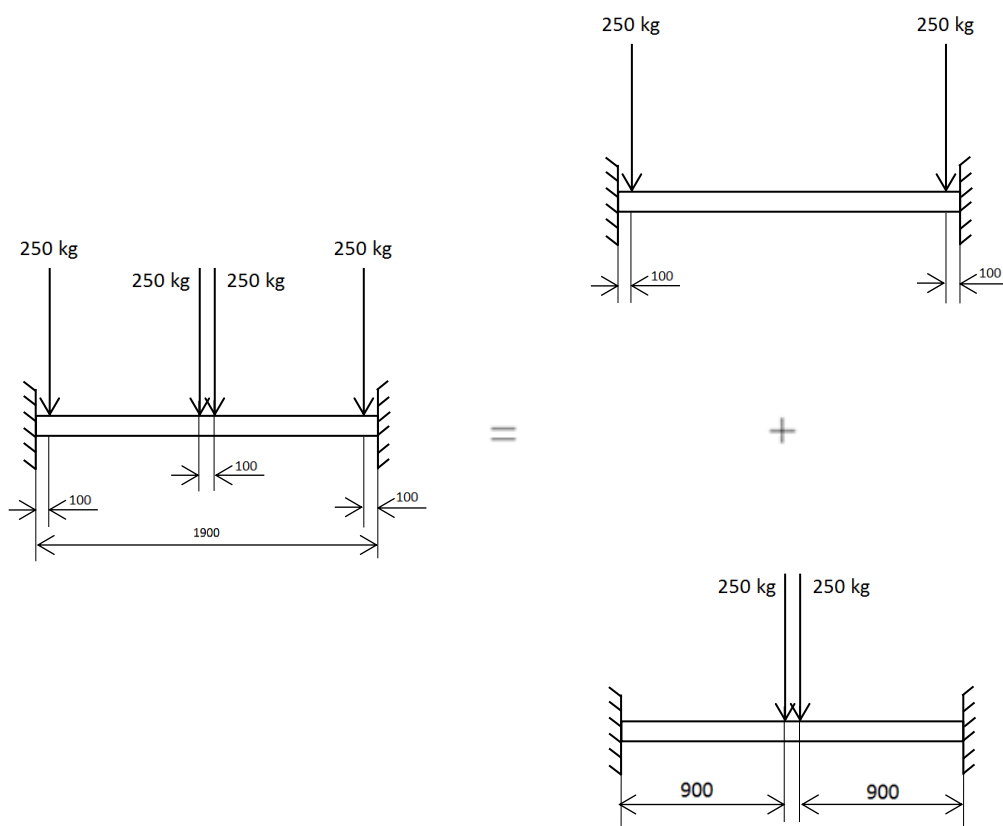
Height (mm)	Width (mm)	Thickness (mm)	Inertia (cm ⁴)
60	40	2	20,7
60	40	3	29,2
60	40	4	36,1

Table 24. Inertias

Verification:

The total inertia of the section could be decomposed into the sum of three inertias:

$$y_{TOT} = y_{a=0,1m} + y_{a=0,9m}$$



Decomposition of the deflections in order to simplify the calculations

The deflection is estimated with the following values, corresponding to our bar:

F is 2452 N (250 x 9,81)

a is 0,1 m and 0,9m

L is 1,9 m

E is a constant and takes value for iron $200 \cdot 10^9$ N/m²

I is $2,07 \cdot 10^{-5}$ m⁴

Finally, the total Inertia:

$$y_{TOT} = 0,001 \text{ mm} + 0,042 \text{ mm} = 0,043 \text{ mm}$$

The maximum deflection allowed, according to the Spanish Normative (UNE), is:

$$y_{NORM} = \frac{L}{500} = 3,8 \text{ mm}$$

Therefore, the normative is accomplished:

$$y_{NORM} = 3,8 \text{ mm} > y_{TOT} = 0,043 \text{ mm}$$

Design of the shelves

Concerning to the design of the shelves, must consider different aspects about the products:

- Differentiation between nonflammable and flammable goods: the pallets containing flammable product will be stored in separate shelves.
- The height of the different types of pallets: each type of pallet has a different height, so that conditions the measures that each level of the shelves must have, the space should be optimize as much as possible.

- Pallet types: the pallet type 4 is half pallet because its measures are 800x600. This fact gives the possibility that the management can be performed in pairs (as if it were a Europallet 1200x800).

Proportion of each pallet in relation with the total:

Pallet	% of the static capacity
1	0,387
2	0,194
3	0,161
4	0,258
Static capacity	1550

Table 25. Percentage of pallets

The next table shows the amount of different pallets taking into account that the pallets 4 are manipulated in pairs:

Pallet	Number of pallets
1	9240
2	4620
3	3850
4	3080

Table 26. Number of pallets

Moreover, it is important for calculations to differentiate the heights of each type of pallet, the levels will be dimensioned according to the heights. The quantities of pallets for the next table are extracted from the proportions shown in the "table 25", considering that 30% of the pallets 1, 2 and 3 contain flammable product:

Pallet	Height (mm)	Flammable	Not Flammable	Total
1	0,8	2772	6468	9240
2	1,25	1386	3234	4620
3	2	1155	2695	3850
4	1	0	3080	3080

Table 27. Amount of pallets according to the height

Once it has identified the amounts of pallets for the different heights and the pallets classified among flammable and nonflammable, it can determine the position of the rack in which will be placed according to their height.

Will be taken into account that the warehouse capacity will increase by 10% to cover future demands or demand spikes.

Therefore the number of places that should be designed for each type of pallet will be:

Pallet	Height (mm)	Flammable	Not Flammable	Total Flammable	Total Not Flammable	Total
1	0,8	2772	6468	3049	7115	10164
2	1,25	1386	3234	1525	3557	5082
3	2	1155	2695	1271	2965	4235
4	1	0	3080	0	3388	3388

Table 28. Total amount of spaces

To store will have a useful height of 20 m, then calculate the total number of pallets that will fit by module according to their height.

Pallet	Height (mm)	Total amount of places	Real amount of places	Places per module	Flammable	Not Flammable	Total amount of modules
1	0,8	20,83	20	40	76,23	177,87	254,10
2	1,25	14,18	14	28	54,45	127,05	181,50
3	2	9,26	9	18	70,58	164,69	235,28
4	1	17,24	17	34	0	99,65	99,65

Table 29. Total amount of modules

Pallet	Total amount of Flammable modules	Total amount of Not Flammable modules	Real amount of Flammable places	Real amount of Not Flammable places	Total
1	77	178	3080	7120	10200
2	55	128	1540	3584	5124
3	71	165	1278	2970	4248
4	0	100	0	3400	3400

Table 30. Real amount of spaces

Width of the corridors

According to the technical characteristics of transelevators, will be a width of corridor of 1970 mm, for the circulation of the shuttle. Likewise, to the providers in the technical specifications of the shuttles will include as a requirement the realization of a dual career in the shuttle that allows that any transelevator can enter in any corridor, since otherwise should dedicate to a single aisle slave use of shuttles (operationally interrupting the system and with the need for a higher investment).

Total area of the Silo

It is a well-known that automatic rectangular stores give best results as the square ones, therefore will be match a rectangular geometry from the warehouse.

It has been assumed that the width of each module is 1980 mm corresponding to the width of two pallets (800 mm + 800 mm) and its clearance of 100 mm with side supports and between themselves and the width of supports that are 80 x 80, therefore will have:

$$40 + 100 + 800 + 100 + 800 + 100 + 40 = 1980 \text{ mm}$$

The depth of the modules will have a value of 1300 mm this corresponds to the depth of each pallet 1200 mm and 50 mm of clearance that it leaves at the beginning and at the end of each place:

$$50 + 1200 + 50 = 1300 \text{ mm}$$

Therefore the area occupied by each module will have a surface of:

$$1,98 \times 1,3 = 2,574 \text{ m}^2$$

The total number of modules will be 774 therefore the total area occupied by the silo without counting aisles will be:

$$774 \times 2,574 = 1992,276 \text{ m}^2$$

Fixing the longitudinal side in 100 m the dimension of the other side is obtained:

$$100 \times L = 1992,276 \Rightarrow L = 19,92 \text{ m}$$

Side of 22,14 m length is obtained, therefore the final dimensions of the warehouse will be 100 x 19.92 regardless of corridors that are introduced below:

Longitudinally by aisle would be 50 modules:

$$\frac{100000}{1980} = 50,50 \text{ modules}$$

The required number of aisles it will be determined bellow:

$$50 \times 2 = 100 \frac{\text{modules}}{\text{corridor}}$$

$$\frac{774 \text{ modules}}{100 \frac{\text{modules}}{\text{corridor}}} = 7,74 \sim 8 \text{ corridors}$$

Therefore the silo will have the capacity for $100 \times 8 = 800$ modules and it final sizes will be:

Length:

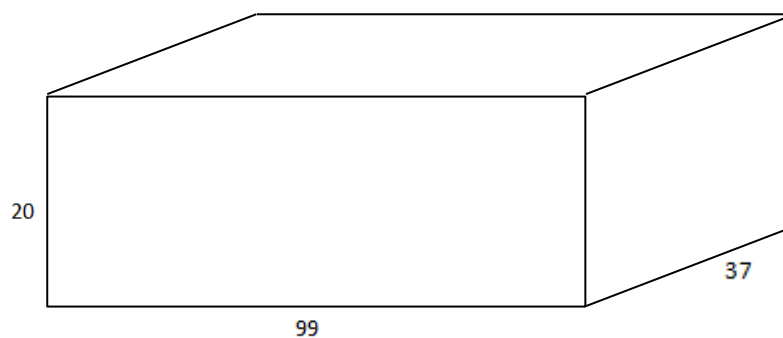
$$1,980 \times 50 = 99 \text{ m}$$

Width:

$$8 \times 1970 + 1300 \times 2 \times 8 = 36,56 \text{ m}$$

The total area of the silo will be:

$$99 \times 37 = 3663 \text{ m}^2$$



The shelves of the Silo description

The silo consists of narrow aisle shelving suitable for transelevators, with the reception and the expedition will be in different points. Each linear shelving will be endowed with a table for centred the load on each end of the linear to place the pallet in the correct way.

For a better analysis of the next schemes, as well as some that will be show at successive chapters, should take into consideration the following definitions:

- The module is the minimal part of a warehouse, and is composed of 2 supports (also called frames) that support the beams on which pallet are located, at different levels.
- Is called "linear" to the straight set of modules.
- Are called "levels" to the number of heights which can be stock in a module.
- Is called "place" to the place where the pallets will be located in the silo.

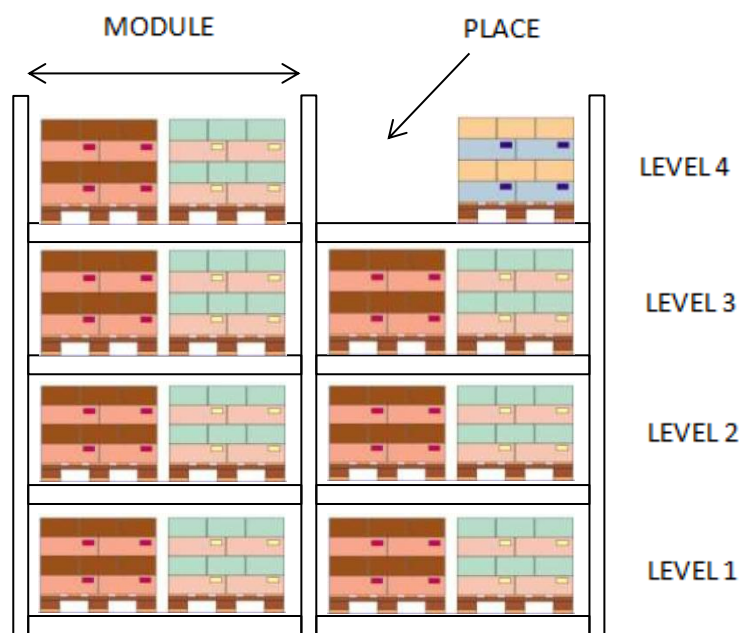


Image 18. Scheme of shelves

TECHNICAL DATA

The automated systems of storage and automated systems of transportation work together in different points of the warehouse under the supervision of the WMS (Warehouse Management System) which manage the different operations of the systems. To be considered as such, and not a simple stock management, the program has not only manage the locations of the products, but also the movements of operators and machines responsible for the maintenance of articles.

Within this section include all transport equipment necessary for the operation of the inputs of goods, preparation of orders, and delivery, as well as unique equipment: labellers, control of gauge, etc.

The disposal of the equipment is indicative; the end-user must adapt the installation according to the functional description of the specifications, experience and standards of transportation.

The installation is mainly divided into:

- Transelevators or shuttles.
- Transferers.
 - Transfer bridges.
 - Shuttle trucks.
- Tables delivery and accumulation of pallets
- Gauge controls.
- Output full palette.
- Unique items

Introduction and objectives

The objective of this chapter is to explain the methodology to follow in the new facilities, also exposing the technical specifications of the behavior of the software and control systems required for the correct operation and the safety of the new facilities.

Work Processes

Identification and control of pallets coming from reception area, until their entry into the system.

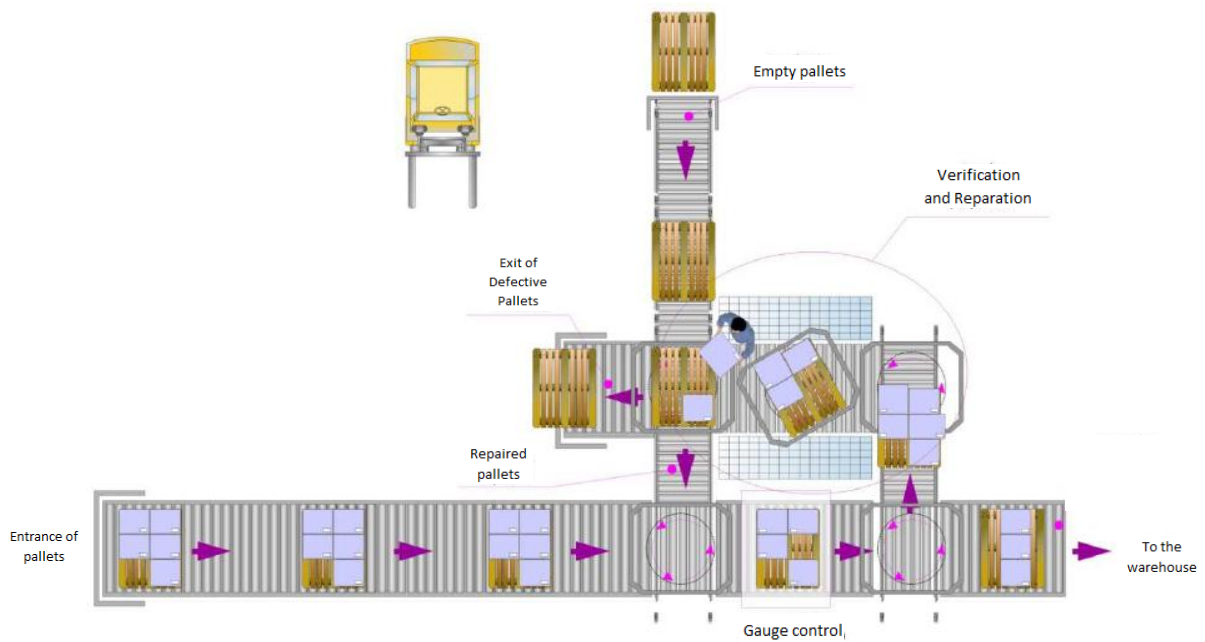
After reception of pallets, these are labeling, finally, they pass through a gauge control.

Once the pallets are received, the system generates a unique code for each one. This order is received by the printing system. The decal is printed and pasted automatically on the merchandise. This label will be that the system uses to recognize the goods and located it during their stay in the warehouse.

The gauge control functions are shown below:

- Check the height of the pallet (type of height).
- Verify the dimensions of the pallet (load type).
- Verify the dimensions of the pallet (pallet type).
- Verify volumetric correction of the merchandise.
- If there is any discrepancy between the expected data and data which casts the gauge control will block the passage of the pallet and a luminous or acoustic signal will be activated.
- If all the checks are satisfied, the pallet goes into “ready-access to the silo”.

Below is an scheme of the gauge control process:



The system will be composed of the following chapters for each operative line:

- The pallet label printing.
- The label must be equipped with barcode for internal use. The use of EAN-13, GS1-128 label or other standard will be studied.

The information associated with the barcode of each pallet must contain the following concepts:

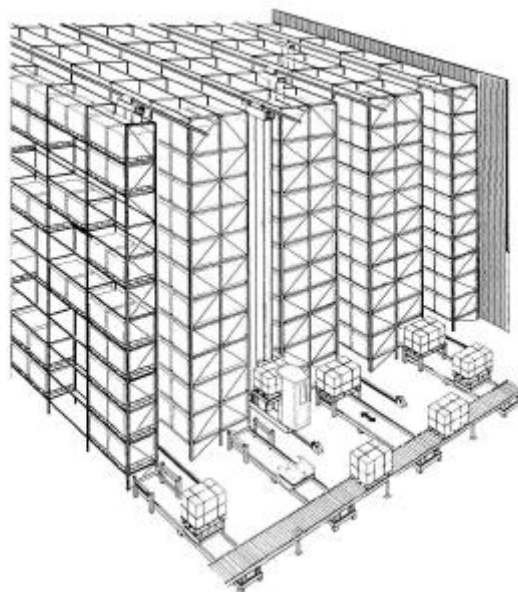
- Product code.
- Name of product.
- Number of batch.
- Date of manufacture.
- Expiration.
- Flammable (yes/no).
- Toxic (yes/no).
- Type of palette.
- Type of height.

Mechanical shift from the pallet to the silo

The transition of palletizing product to silo it is solved mechanically through a system of multiple-entry with trolley shuttle. This trolley shuttle connects or delivers the incoming pallets in the warehouse to the transfer bridges.

Bridges of transshipment, will be a double feature as exchangers of the shuttles and as feeders of pallets to the corridors. I.e. they will take place:

- The supply of goods to each corridor without the use of the shuttle between the operation.
- Change of the shuttles to another corridor.
- Delivery of the pallet to the corridors will be made with a centring table of accumulation of pallets (2 units max) of entry located at the head of each corridor.



Algorithm of location (destination management of pallets that will input in the system).

The location algorithm will start to operate at the time in which truck shuttle pick up a pallet for transporting it to the header of the corridor.

The sequencing will be:

- First find the right corridor.
- Secondly, the ideal place within the corresponding aisle.

The reason to look for first corridor and not the place simply is because management system will seek a corridor that is occupied by a shuttle.

The computer system of allocation of locations must manage the following concepts:

Choice of Corridor:

The system will manage the following criteria of decision and functionalities.

- Management of areas dedicated to different types of product.
- Priority of service to active corridors (those in which the shuttle is working and there is a place in accumulator head of corridor).
- Dispersion of a same reference in the maximum number of corridors.
- Direct output of product in stock break and custom orders. There will be a direct flow, the pallet will entry in the system and directly will go to the expedition area.

Choice of space within the corridor concepts to manage by system:

- Restrictions on location, flammable products may only be stored in a specific area of the warehouse.
- Type of load locations.
- Locations by type of height (management of heights).
- Restrictions of incompatibility within the stack. Management of table of incompatibilities.

Membership of the product to a location preference area. In this case the preferential location of these products of linear flow area is determined by:

The horizontal distance from the area of expedition, which is reserved for these products.

Height: lower higher level classification ABC.

ABC analysis is a way of classifying products according to pre-established criteria, most of the texts that handled this issue, take as criterion the value of inventories and give relatively arbitrary percentages to make this classification. For example, 10% of products represent 60% of the purchases of the company therefore this is zone A, 40% of products 30%, which would be those who are located in zone B, the rest (50% of the products and 10% of purchases) are products C.

The above values are arbitrary, each company has its particularities, if someone decides to use this criterion should be aware of the realities of your business. It is important think not only in costs, and see other criteria, which is undoubtedly the main difficulty in this type of analysis. It is undeniable that a small percentage of products from any criteria, it is indispensable for the correct functioning of the company or to improve their profitability, the company would be classified as typical, and according to this point of view products van by selecting products from other areas; If one deems appropriate could think on the possibility of adding a D, for really inconsequential products and very low cost.

Prioritization shuttle work orders (point source management).

In this case there are two different cases in the implementation:

1 Shuttle in reception area:

Truck Shuttle, when going to take up the pallet, shall elect one or another entry on the basis of the following concepts:

- Priority entrance with highest number of pallets in a waiting position.
- Proximity of the entrance.

2 Shuttle in area of expedition of outputs of pallets as full pallet.

The truck will extract complete pallets for expedition. The decision of which pallets serve and to which place of departure, will be taken on the basis of the following criteria:

- Priority to the output with highest number of pallets in a waiting position.
- Proximity of the exit.

Work order processing

This is the process that transforms the queue of orders that have entered in the system in orders of work necessary to make up the flow of outputs.

The processes are the next ones:

A. Separation of the complete pallets for a single client of the global warehouse orders.

- These complete pallets to prepare are separated from the rest and will generate a queue of activities for:
 - The shuttles: these will generate output of full pallet orders to formed a queue of exit motions of full pallet (removal of the palette, delivery to the full pallets to output device).
 - Automatic reading of the bar code of the outbound pallet in the position of picking.
 - Expedition palette label printing, for delivery to the customer (name, address, carrier, download,...).
 - Gluing of label for each expedition palette.

B. Grouping of orders by lots.

- The grouping of orders allows the formation of lots of the same carry agency orders.
- The process of grouping should be easily configurable warehouse management program.
- The issuance shall be completed when:
 - The pallet would be taken and it would be placed it in the corresponding table.
 - The operator with trolley stowage the pallet of the table (dynamic accumulation tables by gravity) and enter it into the corresponding truck.

Below is a chart of the detail of a dynamic table:



Image 19. Dynamic Table

The shuttles will be combined movements of entry and exit of goods in the sequence of three phases:

- 1 Collecting the pallet in the reception area and location in the correct place.
- 2 Collecting the pallet in shelf and transportation to expedition area.
- 3 Reorganization of the warehouse.

If at any time there are no pallets waiting in some of the areas of input corresponding to the time of the cycle, or there are no orders in the queue of orders the phase in question shall be deleted.

AVERAGE CYCLE TIME OF SHUTTLES

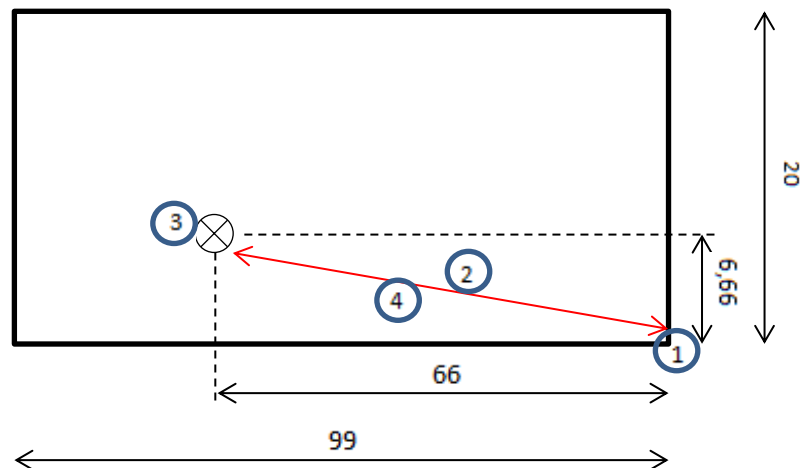
In accordance with the Spanish recommendations for automated warehouses it is possible to calculate the cycle time between some of the shuttles as the time required for pick up a pallet, advance up to go $\frac{2}{3}$ parts in longitudinal way and $\frac{1}{3}$ part of the area possible in the shelf vertically, place the pallet and return to point of origin adding computational times.

It would be equal to a combined cycle but would add once leaves the pallet moving to coordinate longitudinal distance $\frac{1}{3}$ and $\frac{2}{3}$ of the distance vertically to get a pallet and take it back to the point of origin. Below are calculated both times:

Operation	
Loading	6 s
Acceleration with load	0,5 m/s ²
Transportation with load	3 m/s
Deceleration with load	0,5 m/s ²
Unloading	6 s
Acceleration with no-load	1 m/s ²
Transportation with no-load	5 m/s
Deceleration with no load	1 m/s ²
Computational	1,5 s
Average time changing corridor	10

Table 25. Different velocities, accelerations and times required for the operations

Simple Cycle



1 Loading pallet

2 Acceleration with load, transportation with load and deceleration with load

3 Unloading pallet

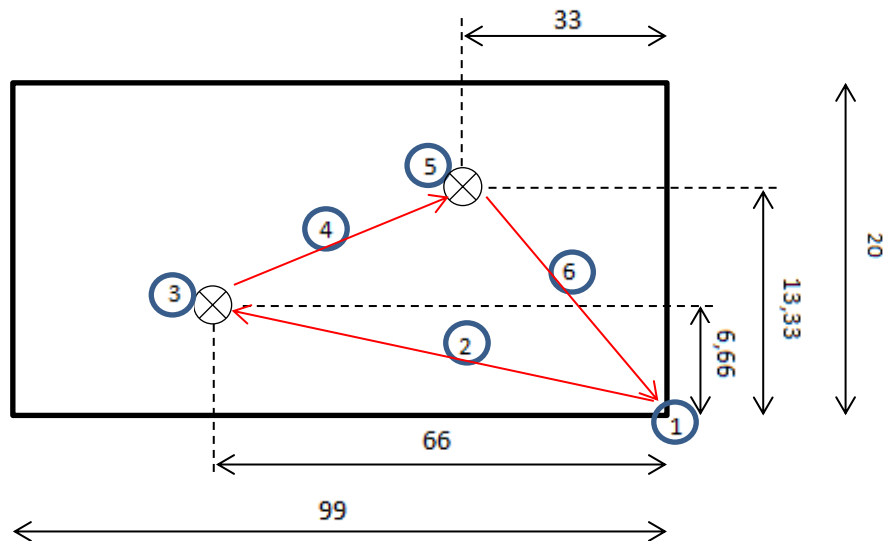
4 Acceleration with no- load, transportation with no-load and deceleration with no-load

Below will be calculated time required for this operation:

Operation	Seconds
Loading time	10
Acceleration time with load	6
Transportation time with load	16
Deceleration time with load	6
Unloading time	10
Acceleration time with no-load	5
Transportation time with no-load	10,7
Deceleration time with no load	5
Computational times	1,5
Average time changing corridor	10
TOTAL	80,20

Table 26. Total time required for a simple cycle

Combined Cycle



1 Loading pallet

2 Acceleration with load, transportation with load and deceleration with load

3 Unloading pallet

4 Acceleration with no- load, transportation with no-load and deceleration with no-load until next location

5 Loading new pallet

6 Acceleration with load, transportation with load and deceleration with load and unloading pallet

Below will be calculated time required for this operation:

Operation	Seconds
Loading time	10
Acceleration time with load	6
Transportation time with load	16
Deceleration time with load	6
Unloading time	10
Acceleration time with no-load	5
Transportation time with no-load	4,1
Deceleration time with no load	5
Loading time	10
Acceleration time with load	6
Transportation time with load	5
Deceleration time with load	6
Unloading time	10
Computational times	1,5
Average time changing corridor	10
TOTAL	110,60

Table 27. Total time required for a combined cycle

RECEPTION AND EXPEDITION AREA

Reception Area

During the year, the volume of arrivals in the warehouse is constant and equal to 1550 pallets/day, except for the month of December, when the volume is less and equal to 1085 pallets / day. However, the area must be dimensioned for the biggest volumes of inputs, which mean 1550 pallets / day.

The arrivals of the pallets are made from 6am to 16h. Assuming that inputs are constant distributed in time, we have:

$$\frac{\text{Inputs}}{\text{Hour}} = \frac{\text{Inputs}/\text{day}}{\text{Inputs}/\text{day}} = \frac{1550}{10} = 155 \text{ Inputs/h}$$

Therefore, trucks bring to the store 155 pallets per hour from 6h to 16h.

As the initial data shows, inputs works happen between 6 to 16, and outputs between 8 and 20. Therefor will be 2 hours with only inputs between 6 to 8, between 8 to 16 will be 8 hours of

inputs and outputs at the same time and after that between 16 to 20 will be 4 hours of only outputs.

Taking into account that the average amount of outputs/h it is 180,83 pallets and the time for a simple cycle it is 80,2 seconds and the combined cycle it is 110,6 the performances will be:

$$155 \frac{Inputs}{h} \Rightarrow 2,58 \frac{pallets}{min}$$

The warehouse has 6 transelevators each one can do the simple cycle in 80,2 seconds, then:

$$80,2 \frac{seconds}{simple\ cycle} = 1,34 \frac{min}{\frac{simple\ cycle}{transelevator}}$$

6 Transelevators could carry 4,47 pallets/min

$$4,47 > 2,58$$

During the two first hours will not be queues in the system.

Below the system is checked for the next 8 hours: Let assume that the inputs will be the more restrictive.

$$180,83 \frac{Pallets}{h} \Rightarrow 3,01 \frac{pallets}{min}$$

The warehouse has 6 transelevators each one can do the combined cycle in 110,6 seconds, then:

$$110,6 \frac{seconds}{combined\ cycle} = 1,84 \frac{min}{\frac{combined\ cycle}{transelevator}}$$

6 Transelevators can move 3,26 pallets/min

$$3,26 > 3,01$$

During the eight next hours will not be queues in the system.

Expedition area

For the sizing of the departure area, it proceeds similarly as for the reception area.

The volume of output pallet store will vary throughout the year and reach the peak in November, when 2170 departures / day are expedited. It must size the departure area for this maximum value. However we must note that the number of the workers depends on seasonality.

The output of the pallets is made from 10h to 22h. Assuming that the outputs are uniformly distributed:

$$\frac{\text{Outputs}}{\text{Hour}} = \frac{\text{Outputs/day}}{\text{Hours/day}} = \frac{2170}{12} \approx 180,83 \text{ Outputs/h}$$

$$180,83 \frac{\text{Pallets}}{h} \Rightarrow 3,01 \frac{\text{pallets}}{\text{min}}$$

The warehouse has 6 transelevators each one can do the simple cycle in 80,2 seconds, then:

$$80,2 \frac{\text{seconds}}{\text{simple cycle}} = 1,34 \frac{\text{min}}{\frac{\text{simple cycle}}{\text{transelevator}}}$$

6 Transelevators could 4,47 pallets/min

$$4,47 > 3,01$$

During the two first hours will not be queues in the system.

This analysis suggests that in the system queues will not form at any time. The margins obtained can be used to perform maintenance without stopping the system or for access to the system during working hours.

Due to the system has time clearance also could perform machines relocation of goods or cover possible unexpected demand peaks in the future.

Thanks to the analysis also it is possible to obtain the dimensions of the reception area and the expedition area. In view of the results, it is not necessary to give the store a buffer for the pallets in the reception area. However, in the expedition area will be necessary some extra space where pallets can wait to be placed in the corresponding truck.

Therefore the reception area will be equipped by the offices and the installations for the employees , gauge control, labeling and mechanical tapes where pallets will be positioned in front of each exchanger to be arranged in each shuttle to be transported to their corresponding location in the silo.

The expedition area will be equipped with labeling area, picking area, expedition buffer area and all of mechanical tapes where pallets will be positioned after silo for been dispatched by the corresponding place, picking area or directly to the docks.

Reception Area Sizing

Maximum input of pallets / day produced in the 12 months of the year is 1550 pallets (day). 10 hours will be considered because the pallets can be delivered from 6:00 to 16:00 h.

$$\frac{1550 \text{ pallets}}{1 \text{ day}} \times \frac{1 \text{ day}}{10 \text{ hours}} = 155 \text{ pallets/hour}$$

The capacity of each truck container is 32 pallets. Therefore every hour five trucks arrive.

$$\frac{155 \text{ pallets/h}}{32 \text{ pallets/truck}} = 4,85 \text{ truck/h}$$

As in the conventional warehouse, the calculations for the reception area are the same so 3 docks will be necessary. Finally, in order to be covered against changes in future demand, peaks of demand, reparations, etc. other dock will be added.

Due to there will be not queues in the reception area the minimum dimensions for contain all the devices and services that the warehouse requires in this area will be $37 \times 20 = 740 \text{ m}^2$.

Expedition Area Sizing

To size the docks in this area the same process is performed as for the reception area. In this case the maximum output per month amounts to 2170 pallets per day. In this case outputs trucks are performed for 12 hours in a day.

$$\frac{2170 \text{ pallets}}{1 \text{ day}} \times \frac{1 \text{ day}}{12 \text{ hours}} = 180,8 \text{ pallets/h}$$

$$\frac{181 \text{ pallets/h}}{32 \text{ pallets/truck}} = 5,65 \text{ trucks/h}$$

$$\frac{60 \text{ min}}{5,65 \text{ truck/h}} = 10,61 \frac{\text{min}}{\text{exit}} \text{ truck}$$

Due to the calculations are the same as in the conventional warehouse 3 docks will be necessary. But trying to cover against schedule changes, reparations, etc. other dock will be added.

Due to there will be not queues in the expedition area the minimum dimensions for contain all the devices and services that the warehouse requires in this area will be $37 \times 25 = 925 \text{ m}^2$.

PICKING AREA

Some customers have orders of products with different quantities of goods. For this reason it also has to be designed a picking area in the automated warehouse.

According to the data product 4 does not required picking, 30% of pallets 1, 40% of pallets 2 and 3.

The picking area is used to prepare orders for products from different pallet output orders. For this reason the position of the picking area will be situated in front of the expedition area of the warehouse. The maximum output per day is 2170 pallets / day, and the percentages of the different pallets are:

Kind of pallet	Percentage of output	Max outputs pallets	Number of pallets for picking
1	38,71%	840	252
2	19,35%	420	168
3	16,13%	350	140
4	25,81%	560	0
Total		2170	560

Table 25. Pallets for picking

The total amount of pallets for picking results 560 pallets / day, operators picking work for 12 hours, 47 pallets / hour will be picked.

The inputs in the picking area must be constant, so finally it has decided to retain in the picking area a minimum stock of pallets of each type, a total amount of 32 pallets, without stack up.

The sizing of the picking area is calculated based on the sizes of the 32 pallets:

$$A = \text{pallets} * \text{width pallet} * \text{length pallet}$$

$$A = 32 * 0.8 * 1.2 = 30,7 \text{ m}^2$$

Furthermore, it should be taken into account that for the correct perform of the operator activities this surface will be multiply 4 times, the final result is 122,8 m².

REQUIRED OPERATORS

As in the conventional warehouse only three docks will be used at the same time in both cases (reception and expedition). Two workers are required for load a truck so 2 x 3 = 6 operators for the reception area and 2 x 3 = 6 operators in the expedition area, in total 12 workers only for load the trucks.

In the gauge control will be necessary 2 workers, 2 more for picking area and for the maintenance of the warehouse 2 operators more.

For the offices let assume that will need 2 workers.

In total this warehouse can work with the total amount of 20 operators.

WAREHOUSE FEATURES

STRUCTURE

As have been mentioned in previous points warehouse will be composed for 3 bodies, two of them for reception and dispatch and one for storage.

The silo or body B, does not require structure, because it is a self-supporting warehouse, shelves will do the function of structure, over it the cover and the walls will be supported.

In the other two bodies, structure will be needed, and in this case will be a prefabricated structure formed by pillars, prefabricated beams resting on them, and joist resting on the beams, so the cover will rest on the joist.

Reception area and expedition area will have the same structure than the conventional warehouse:

Pillars with square morphology with side 0,40 m and a height of 10 m and concrete HA-250.

FOUNDATION

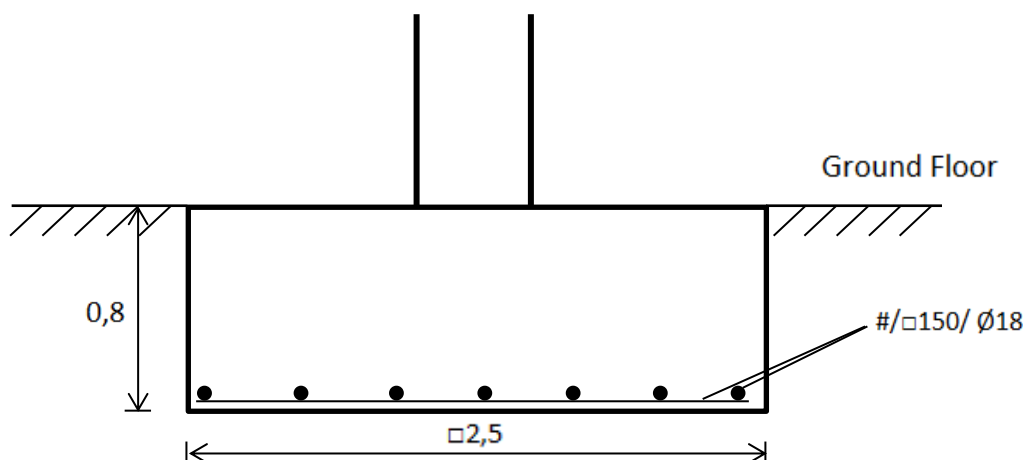
Reinforced concrete flooring

Concrete deck

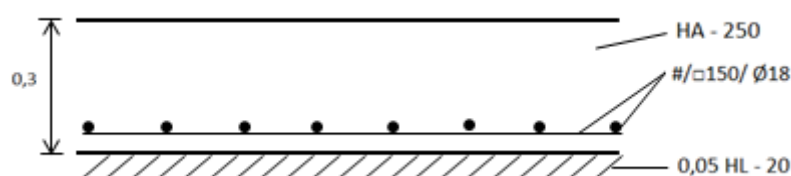
The ground level will be screed 1.2 m above the level of the plot in the bodies A and C of the warehouse. In the silo ground level will coincide with the plot level 0.00.

The foundations for the reception area and expedition area will be:

- Reinforced concrete basement with the next characteristics:



- Reinforced concrete flooring with the next characteristics:



- The outsides of the warehouse will have next characteristics:

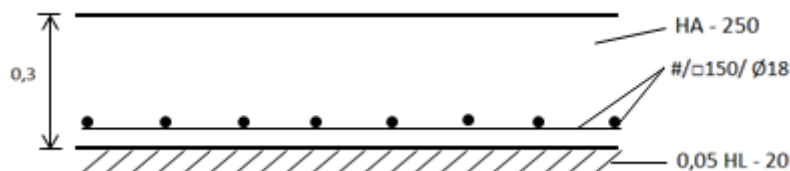


SLAB

Structural characteristics of slab in the silo:

- Will use concrete HA25-IIa.
- The calculation of the thickness of the slab and foundation of it and the definition of their armor will be carried out taking into account:
 - The geotechnical characteristics of the terrain.
 - The loads of the same. These charges will be depending on:
 - The shelf loads: 14.763 kg./m². Equivalent to 9.500 Kg/vertical support (for a rack of 2 pallets/module).
 - The structure loads.
 - Loads of machinery:
 - Shuttles :Supported on a rail: maximum load at the points of support of rail: 7 Tm, every 0.8 m.
 - Machinery: They will be considered 1,500 kg. per m².

The slab will have the next characteristics according to other similar projects:



COVER AND WALLS

Cover and walls will be Deck-type single-layer, composed by veneer, insulation and asphalt, for waterproofing.

At the same time on the deck will be pipes to evacuate the water accumulated on their surface and avoid possible accumulations of water.



Image 20. Single deck layer

DRAINS

Although any spill is not expected, by the characteristics of the storage is needed a drainage system able to collect liquids spilled potentially due to breakage of a container vessel diesel oil or any hazardous material, leading them to a safe place.

- Automatic Silo: there will be a system consisting of a gutter run along each corridor, parallel, therefore, all the gutters will shed at the same time on a perpendicular collector to them that take the potentials liquids spilled in a safe deposit.
- Reception area and Expedition area: will have a drainage system with discharge into drains that will channel the liquids into a save deposit.

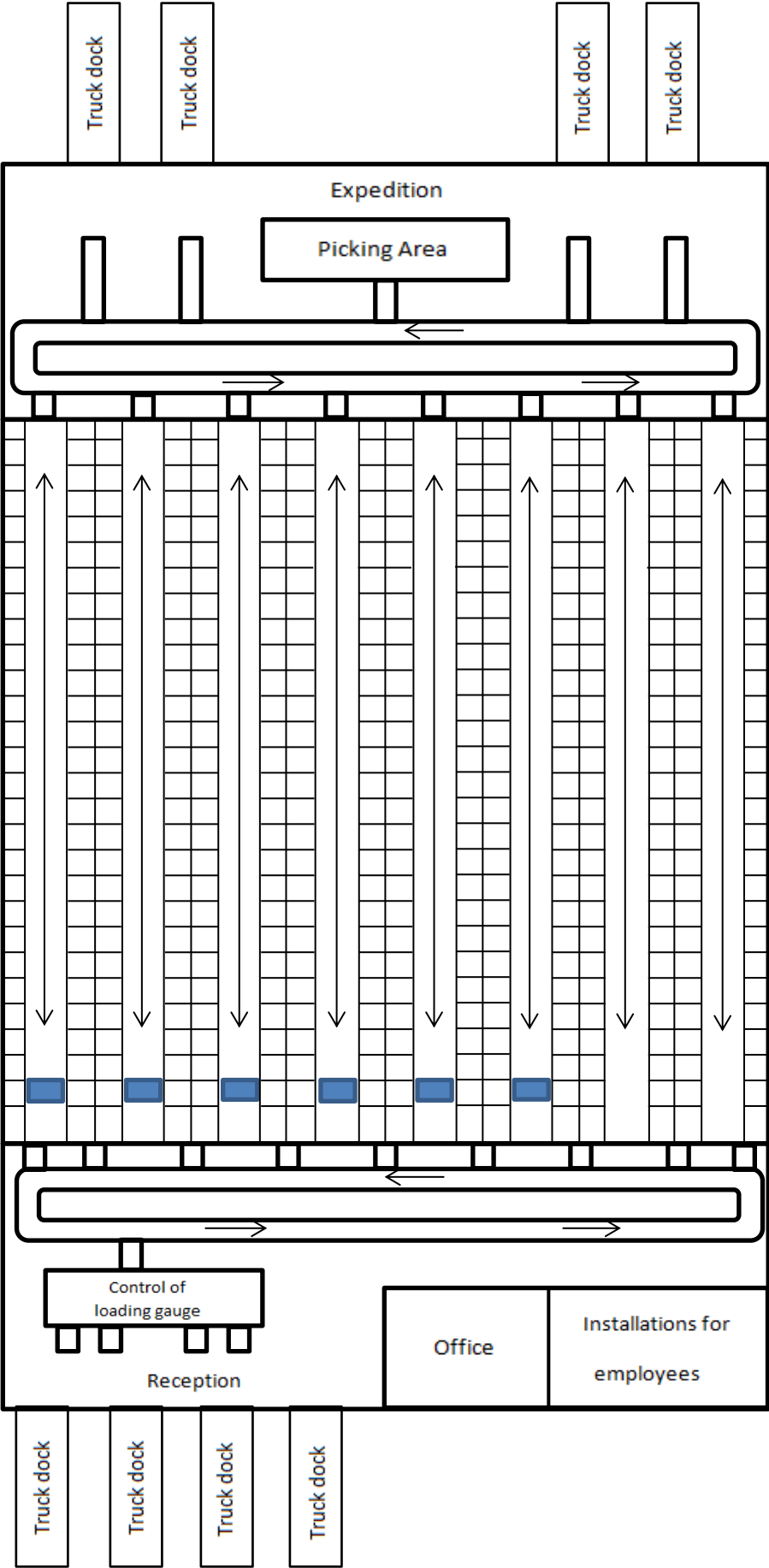
FIRE MECHANISM

Security measures:

There will be a system of forced ventilation, with a minimum of 0.3 m³/min and m².

The fire protection system shall consist in an automatic water sprinklers located on the roof, with an intensity of 12.5 liters / min*m². Also equipped fire hydrants and portable fire extinguishers shall be installed.

FINAL DESIGN



BUDGET

CONVENTIONAL WAREHOUSE

CONVENTIONAL WAREHOUSE				
Process	Quantity	Units	€/Unit	Total
Foundations				
Required Land	13250	m ²	22,00 €	291.500,00 €
Earthwork	6112,5	m ³	15,00 €	91.687,50 €
Pillars	285	Unit	300,00 €	85.500,00 €
Beams	285	Unit	400,00 €	114.000,00 €
Concrete basement	285	Unit	300,00 €	85.500,00 €
Construction process				
Outside wall	5568	m ²	60,00 €	334.080,00 €
Roof	12669	m ²	46,00 €	582.774,00 €
Glazed roof	450	m ²	100,00 €	45.000,00 €
Concrete base	12600	m ²	40,00 €	504.000,00 €
Asphalted surface	5000	m ²	40,00 €	200.000,00 €
Equipment				
Luminaires	350	Unit	2,00 €	700,00 €
Electrical Wiring	1500	m	0,50 €	750,00 €
Outlets	60	Unit	2,00 €	120,00 €
Doors	10	Unit	50,00 €	500,00 €
Pipes	400	m	3,00 €	1.200,00 €
Fire prevention Pipes	1200	m	4,00 €	4.800,00 €
Sanitary systems	8	Unit	100,00 €	800,00 €
Specified Equipment				
Shelves	35	Unit	700,00 €	24.500,00 €
Fork- lifts	15	Unit	8.000,00 €	120.000,00 €
Manual fork-lift	12	Unit	1.000,00 €	12.000,00 €
TOTAL				2.499.411,50 €

The budget has been divided in different groups:

- Foundations
- Construction process
- Equipment
- Specified Equipment

The rest of the expenses as operational costs or workers' salaries are not included in this budget.

It is important to mention that all the prices are without taxes.

AUTOMATED WAREHOUSE

AUTOMATED WAREHOUSE				
Process	Quantity	Units	€/Unit	Total
Foundations				
Required Land	5328	m ²	22,00 €	117.216,00 €
Earthwork	3700	m ³	15,00 €	55.500,00 €
Pillars Bodies A and C	90	Unit	300,00 €	27.000,00 €
Beams Bodies A and C	90	Unit	400,00 €	36.000,00 €
Concrete basement	90	Unit	300,00 €	27.000,00 €
Metalic Pillars Body B	3200	Unit	280,00 €	896.000,00 €
Metalic Beams Body B	3200	Unit	130,00 €	416.000,00 €
Construction process				
Outside wall Body A and C	164	m ²	60,00 €	9.840,00 €
Outside wall and roof Body B	9103	m ²	25,00 €	227.575,00 €
Roof	1665	m ²	46,00 €	76.590,00 €
Concrete base	5328	m ²	40,00 €	213.120,00 €
Asphalted surface	1700	m ²	40,00 €	68.000,00 €
Equipment				
Luminaires	160	Unit	2,00 €	320,00 €
Electrical Wiring	900	m	0,50 €	450,00 €
Outlets	30	Unit	2,00 €	60,00 €
Doors	10	Unit	50,00 €	500,00 €
Pipes	250	m	3,00 €	750,00 €
Fire prevention Pipes	800	m	4,00 €	3.200,00 €
Sanitary systems	6	Unit	100,00 €	600,00 €
Specified Equipment				
Shuttle	6	Unit	15.000,00 €	90.000,00 €
Interchange	17	Unit	10.000,00 €	170.000,00 €
Conveyor belt	250	m	1.300,00 €	325.000,00 €
Manual fork-lift	12	Unit	1.000,00 €	12.000,00 €
Fork-lifts	4	Unit	8.000,00 €	32.000,00 €
TOTAL				2.804.721,00 €

The budget has been divided in different groups:

- Foundations
- Construction process
- Equipment
- Specified Equipment

The rest of the expenses as operational costs or worker's salaries are not included in this budget.

It is important to mention that all the prices are without taxes.

ECONOMIC STUDY

The main aim of the economic analysis that is done below is to serve as a feasibility of the investment in both cases.

Profitability of business evaluation criteria will be used for determine the best solution.

These methods will be based on the flows of funds from investment and their behavior in the short and medium term.

The most frequently criteria used to evaluate and select projects of investment are:

- Recovery or "Pay-Back" period.
- NPV (Net Present Value).
- IRR (Internal Rate of Return).

Description of the methods:

The basic information needed for an analysis of investment is the amount of the initial investment and cash flow expected during the useful life of the investment, it means the cash financial flow.

Below is the table of cash flow. In box year 0, appears the value of the initial investment, which will be the total budget for each case (automated warehouse and conventional warehouse). This amount takes negative value due to represents an initial investment.

Investment and the study will be calculated for 20 years.

In box 1 year, is indicated the profit that will generate each warehouse taking into account (incomes less expenses).

Below are described the benefits and costs for each warehouse.

Income

The incomes in both cases assuming that the average benefit per pallet is the 11 € and knowing the number of pallets that the company sells:

$$18.135 \frac{\text{Pallets}}{\text{Year}} \times 65 \frac{\text{Benefit}}{\text{Pallet}} = 1.178.775 \frac{\text{€}}{\text{Year}}$$

Cost

Conventional warehouse

There will be two kinds of employees; fork lift operators and the rest of workers.

The salary for fork lift operators will be 30.000 € / year and for the rest of the workers will be 23,000 € / year, so the costs per year will be:

$$14 \times 30.000 + 18 \times 23.000 = 834.000 \frac{\text{€}}{\text{Year}}$$

The average cost for maintenance, electricity and other services will be per day 91 €/operative day:

$$91 \frac{\text{€}}{\text{Operative day}} \times 22 \frac{\text{Operative day}}{\text{Month}} \times 12 \frac{\text{Month}}{\text{Year}} = 24.024 \frac{\text{€}}{\text{Year}}$$

$$\text{Total costs } 834.000 + 24.024 = \mathbf{858.024} \frac{\text{€}}{\text{Year}}$$

Automated warehouse

There will be two kinds of employees; fork lift operators and the rest of workers.

The salary for fork lift operators will be 30.000 € / year and for the rest of the workers will be 23,000 € / year, so the costs per year will be:

$$12 \times 30.000 + 8 \times 23.000 = 544.000 \frac{\text{€}}{\text{Year}}$$

The average cost for maintenance, electricity and other services will be per day 53 €/operative day:

$$53 \frac{\text{€}}{\text{Operative day}} \times 22 \frac{\text{Operative day}}{\text{Month}} \times 12 \frac{\text{Month}}{\text{Year}} = 13.992 \frac{\text{€}}{\text{Year}}$$

$$\text{Total costs } 544.000 + 13.992 = \mathbf{557.992} \frac{\text{€}}{\text{Year}}$$

An increment of 2% will consider in the benefits of each year.

Investment		Warehouse	
		Conventional	Automated
Expected Benefit per Year	Year 0	- 2.499.412	- 2.804.721
	Year 1	320.751	620.783
	Year 2	327.166	633.199
	Year 3	333.709	645.863
	Year 4	340.384	658.780
	Year 5	347.191	671.955
	Year 6	354.135	685.395
	Year 7	361.218	699.102
	Year 8	368.442	713.085
	Year 9	375.811	727.346
	Year 10	383.327	741.893
	Year 11	390.994	756.731
	Year 12	398.814	771.866
	Year 13	406.790	787.303
	Year 14	414.926	803.049
	Year 15	423.224	819.110
	Year 16	431.689	835.492
	Year 17	440.322	852.202
	Year 18	449.129	869.246
	Year 19	458.111	886.631
	Year 20	467.274	904.364

Table 26. Cash-Flow

Recovery or "Pay-Back" period

The recovery of the investment or "Pay-Back" period is defined as the period of time, usually expressed in years, which it is necessary to recover the capital invested in the project from the cash flow generated by the project.

Easily it can be calculated using the following expression:

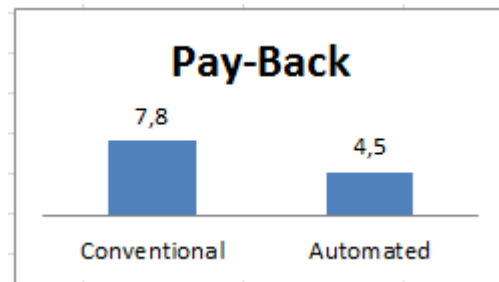
$$P = A/Q$$

Where A is the initial investment and Q the annual profit expected by the investment.

According to this method with lower values of P lower will be the time for recover the investment, therefore better.

Based on "table 26 cash-flow" Pay-back is calculated:

Pay-Back	
Conventional	7,8
Automated	4,5



The automated warehouse will be amortized much faster than the conventional one.

NPV (Net Present Value)

The Net Present Value is defined as the sum of the different cash flows generated by the project over the years of the economic study, discounted to a certain type of interest.

The NPV of an investment is defined as the actualized value of all of expected benefits, i.e. the actualized value of the cash-flow generated. In the function of the value of the NPV, is established a criteria of selection for determine which project is suitable from the economical point of view.

$$Go = -A0 + \sum (Ci - Pi)(1 + k)^{-n}$$

Where:

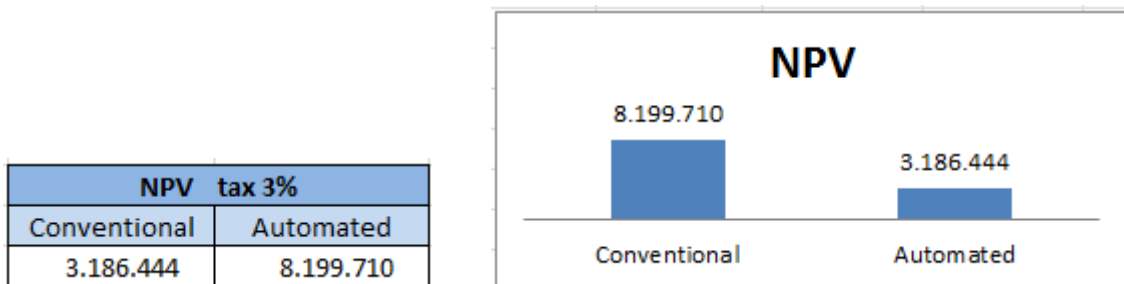
- A0 is the initial investment
- Ci is the total of fees laid down in the period
- Pi is the total of payments laid down in the period
- k represents the interest rate to be used in the calculation.

To determine if an investment is advisable or not, will take into account the value of the NPV.

If $NPV > 0$ investment is advisable. (The investment would produce profits by on top of the required return r).

If $NPV = 0$ the investment is indifferent, would have to be based on other criteria. (The investment would not produce neither gains nor losses).

If $NET < 0$ investment is not advisable. (The investment would produce losses below the required return r).



The highest value of the NPV is for the automated warehouse.

IRR (Internal Rate of Return)

Internal rate of return (IRR) is the interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero.

Internal rate of return is used to evaluate the attractiveness of a project or investment. If the IRR of a new project exceeds a company's required rate of return, that project is desirable. If IRR falls below the required rate of return, the project should be rejected.

From this definition and comparing it with the definition of the NPV is easy appreciate that the internal rate of return is the value you need to take the type of interest " r " in NPV equal to 0.

Depending on the value IRR it is possible to establish criteria for determine if the project could be feasible in an economic point of view.

$$IRR = r \text{ NPV} = 0 = -A_0 + (C_1 - P_1)(1 + r)^{-1} + (C_2 - P_2)(1 + r)^{-2} + \dots$$

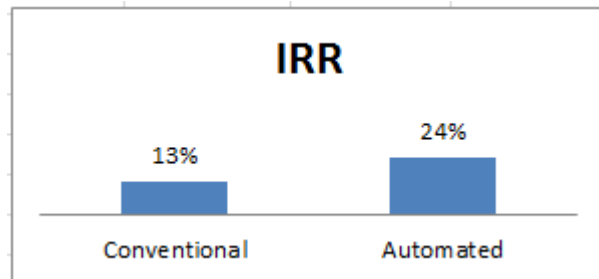
Where " r " is the variable to calculate, k is the return tax fixed by the company in their projects.

If $IRR = r > K$ investment is advisable.

If $IRR = r = K$ investment is indifferent.

If $IRR = r < K$ investment is not advisable.

IRR	
Conventional	13%
Automated	24%



The highest value of the IRR is for the automated warehouse.

CONCLUSIONS

The main conclusion is that in spite of the higher initial investment the economic analysis fully justifies to implement the automated warehouse.

Only with the economic aspects it is possible to say that the automated warehouse is much profitable and also there are other basic aspects such as energy efficiency, the best operative with decrease of errors process, efficiency in real time inventory control and optimization of goods minimizing risks of obsolescence, reinforce the choice of automated warehouse.

BIBLIOGRAPHY

- 1 www.mecalux.es
- 2 Almacenes Automáticos, Mecalux Thyssen, Septiembre de 2009.
- 3 Class master notes of "Storage and Maintenance".
- 4 www.storactlog.com
- 5 <http://vlex.es/tags/normativa-almacenes-825343>
- 6 longboardconsulting.com
- 7 www.uhu.es/javier.pajon/apuntes/zapatos.pdf
- 8 <http://www.archiexpo.es/fabricante-arquitectura-design/zapata-hormigon-10528.html>
- 9 www.swisslog.com
- 10 Fundamentals of Supply Chain Management. Dr Dawei Lu

- 11 Logística Integral: Lean,Supply Chain Management. Bresca Editorial
- 12 http://www.nitc.ac.in/app/webroot/img/upload/content_2855.pdf
- 13 www.zonaeconómica.com